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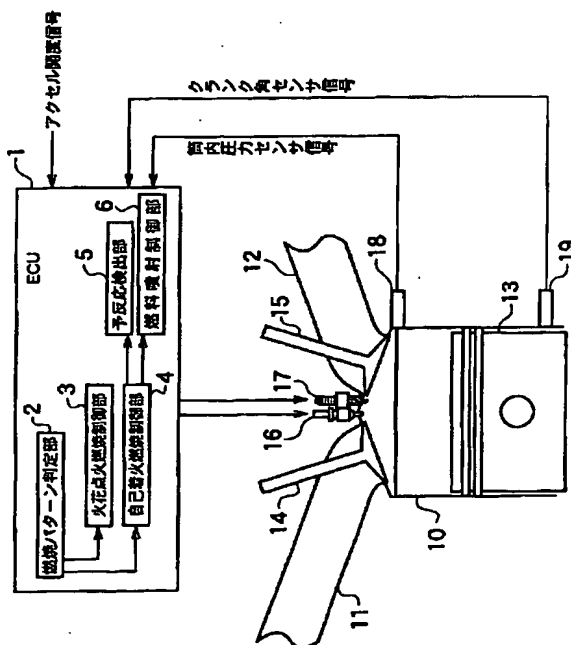
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(54) 【発明の名称】 内燃機関の燃焼制御装置

(57) 【要約】

【課題】 ノッキング及び燃焼不安定を回避するとともに圧縮自己着火燃焼による運転範囲を高負荷側に拡大する。

【解決手段】 燃焼パターン判定部2は運転条件に応じて圧縮自己着火燃焼と火花点火燃焼のいずれかの燃焼方式で運転を行うかを判定する。火花点火燃焼制御部3は火花点火燃焼運転時の燃焼パラメータを制御し、自己着火燃焼制御部4は圧縮自己着火燃焼運転時の燃焼パラメータを制御する。予反応検出部5は、筒内圧力センサ18の検出信号に基づいて圧縮自己着火燃焼運転時に燃焼の予反応を検出し、予反応検出部5が検出した予反応時期に応じて燃料噴射制御部6は燃料噴射量または燃料噴射時期を制御することにより燃焼時期が目標時期となる。



【特許請求の範囲】

【請求項1】 筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、該圧力検出手段が検出した筒内圧力に基づいて着火時期を予測する着火時期予測手段と、該着火時期予測手段が予測した着火時期に応じて圧縮上死点近傍における燃料噴射量または燃料噴射時期を変更する燃料噴射制御手段と、を備えたことを特徴とする内燃機関の燃焼制御装置。

【請求項2】 筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、圧縮自己着火燃焼運転時に少なくとも1回の燃料噴射を圧縮上死点近傍に行うとともに、前記圧縮上死点近傍の燃料噴射時期以前に前記圧力検出手段が検出した筒内圧力に応じて、該サイクルの圧縮上死点近傍の燃料噴射量または燃料噴射時期を変更する燃料噴射制御手段と、を備えたことを特徴とする内燃機関の燃焼制御装置。

【請求項3】 前記圧力検出手段が検出した筒内圧力に基づいて燃料の予反応時期を検出する予反応検出手段を備え、前記燃料噴射時期制御手段は、1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を圧縮上死点から進角した時期に行い、2回目の燃料噴射を圧縮上死点近傍に行い、前記予反応検出手段が検出した予反応時期に応じて、2回目の燃料噴射量または燃料噴射時期を変更することを特徴とする請求項2記載の内燃機関の燃焼制御装置。

【請求項4】 排気上死点近傍で吸気弁及び排気弁が共に閉じている密閉期間を有するように吸排気弁の開閉時期を変更可能な可変動弁装置を備え、

1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を前記密閉期間中に行うことを特徴とする請求項2または請求項3記載の内燃機関の燃焼制御装置。

【請求項5】 前記予反応検出手段が検出した予反応時期が設定値よりも遅角している場合には2回目の燃料噴射時期を補正量分進角するか燃料噴射量を補正量分増量し、予反応時期が設定値よりも進角している場合には2回目の燃料噴射時期を補正量分遅角するか或いは燃料噴射量を補正量分減量することを特徴とする請求項3または請求項4記載の内燃機関の燃焼制御装置。

【請求項6】 運転条件に応じて目標燃焼時期を算出する燃焼時期算出手段を備え、算出された目標燃焼時期が圧縮上死点から遅角している程、前記圧縮上死点付近の燃料噴射時期または燃料噴射量を補正する補正量を大きくすることを特徴とする請求項5記載の内燃機関の燃焼制御装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、運転条件に応じて火花点火燃焼と圧縮自己着火燃焼とを切り換え可能な内燃機関に係り、特に圧縮自己着火燃焼時において、1回又は2回の燃料噴射時期を最適化することによって、燃焼時期を安定化させ、広い運転範囲で圧縮自己着火燃焼を行う内燃機関の燃焼制御装置に関する。

【0002】

10 【従来の技術】ガソリンエンジンの熱効率を改善するために、混合気をリーン化することでポンプ損失を低減すると共に作動ガスの比熱比を大きくして理論熱効率を向上する手法が知られている。しかしながら、従来の火花点火エンジンでは空燃比をリーン化すると燃焼期間が長期化して燃焼安定度が悪化する。このため、空燃比のリーン化には限界がある。

20 【0003】このような燃焼安定度の悪化を避けながら空燃比をリーン化する技術として特開平7-71279号公報にあるように予混合圧縮自己着火燃焼を起こさせる2行程サイクルエンジンが開示されている。予混合圧縮自己着火燃焼では燃焼室の複数の位置から燃焼反応が起こるため、空燃比がリーン化した場合においても火花点火に比べると燃焼期間が長期化せず、よりリーンな空燃比でも安定した燃焼が可能となる。また空燃比がリーンのために燃焼温度が低下し、NO_xも大幅に低減できる。

【0004】

30 【発明が解決しようとする課題】しかしながら、第1の従来例では通常の2行程サイクルエンジン構成としているためガス交換を制御する吸気バルブおよび排気バルブがなく、未燃ガスの吹き抜けが発生し燃費が悪化していた。また、膨張行程はガス交換を行う必要性から後半に排気を行う膨張排気行程となるので、燃焼ガスの膨張による仕事を十分に取り出すことができないため、高負荷運転が困難であるという問題点があった。

40 【0005】一方、自己着火燃焼は空燃比の影響を強く受ける。例えば、高負荷運転を考えると空燃比を濃くした場合には、燃焼反応を起こす燃料量が増加し、燃焼が激しくなりノッキングを起こす。このため、燃焼回数が2回転に1回の通常の4行程サイクルエンジンでは、高負荷での自己着火燃焼による運転が困難であるという問題点があった。

【0006】ノッキングを避けて圧縮自己着火燃焼が成立する負荷範囲を拡大するためには、燃焼時期を圧縮上死点から遅角することが有効である。燃焼時期を遅角すると、ピストン下降時に燃焼が行われるため、ノッキングの原因となる筒内圧力上昇率 $(dp/d\theta)_{max}$ を低減できる。

50 【0007】しかしながら、燃焼時期を遅角した場合には、筒内の圧力、温度が高く保たれる時間が少なくなる

ため、筒内の空気過剰率や温度のサイクルバラツキに対するロバスト性が低下し、燃焼が不安定になるという問題点がある。

【0008】例えば、残留EGRガスは前サイクルの燃焼状態の影響を受けるが、残留EGRガスの温度が変化した場合には、次サイクルの筒内の温度も変化してしまう。従って、燃焼の安定度を考えた場合には、燃焼時期を圧縮上死点から十分に遅角することは困難であった。

【0009】第2の従来技術として、特開平7-217478号公報にあるように、1サイクル中に燃料を2回に分けて筒内に供給する筒内噴射式火花点火機関の燃料噴射装置が開示されている。この従来例は、火花点火機関のノッキングを回避するために、燃料を2回に分けて供給している。しかしながら、第2の従来例では筒内の入、温度状態のサイクルバラツキを考慮して、燃料噴射時期の制御は行っていない。従って、これを圧縮自己着火燃焼に適用した場合には前述したように、燃焼の安定度が悪化するため、高負荷運転が困難であった。

【0010】本発明はかかる問題点に鑑みたもので、その目的は、ノッキング及び燃焼不安定を回避しつつ、圧縮自己着火燃焼による運転範囲を高負荷側に拡大することのできる内燃機関の燃焼制御装置を提供することである。

【0011】また本発明の目的は、圧縮自己着火燃焼による運転範囲を拡大し、燃費、エミッションを改善し、熱効率が高くクリーンな内燃機関を提供することにある。

【0012】

【課題を解決するための手段】請求項1記載の発明は、前記課題を解決するため、筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、該圧力検出手段が検出した筒内圧力に基づいて着火時期を予測する着火時期予測手段と、該着火時期予測手段が予測した着火時期に応じて圧縮上死点近傍における燃料噴射量または燃料噴射時期を変更する燃料噴射制御手段と、を備えたことを要旨とする。

【0013】請求項2記載の発明は、前記課題を解決するため、筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、圧縮自己着火燃焼運転時に少なくとも1回の燃料噴射を圧縮上死点近傍に行うとともに、前記圧縮上死点近傍の燃料噴射時期以前に前記圧力検出手段が検出した筒内圧力に応じて、該サイクルの圧縮上死点近傍の燃料噴射量または燃料噴射時期を変更する燃料噴射制御手段と、を備えたことを要旨とする。

【0014】請求項3記載の発明は、前記課題を解決するため、請求項2記載の内燃機関の燃焼制御装置におい

て、前記圧力検出手段が検出した筒内圧力に基づいて燃料の予反応時期を検出する予反応検出手段を備え、前記燃料噴射制御手段は、1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を圧縮上死点から進角した時期に行い、2回目の燃料噴射を圧縮上死点近傍に行い、前記予反応検出手段が検出した予反応時期に応じて、2回目の燃料噴射量または燃料噴射時期を変更することを要旨とする。

【0015】請求項4記載の発明は、前記課題を解決するため、請求項2または請求項3記載の内燃機関の燃焼制御装置において、排気上死点近傍で吸気弁及び排気弁が共に閉じている密閉期間を有するように吸排気弁の開閉時期を変更可能な可変動弁装置を備え、1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を前記密閉期間中に行うことを要旨とする。

【0016】請求項5記載の発明は、前記課題を解決するため、請求項3または請求項4記載の内燃機関の燃焼制御装置において、前記予反応検出手段が検出した予反応時期が設定値よりも遅角している場合には2回目の燃料噴射時期を補正量分進角するか燃料噴射量を補正量分増量し、予反応時期が設定値よりも進角している場合には2回目の燃料噴射時期を補正量分遅角するか或いは燃料噴射量を補正量分減量することを要旨とする。

【0017】請求項6記載の発明は、前記課題を解決するため、請求項5記載の内燃機関の燃焼制御装置において、運転条件に応じて目標燃焼時期を算出する目標燃焼時期算出手段を備え、算出された目標燃焼時期が圧縮上死点から遅角している程、前記圧縮上死点付近の燃料噴射時期または燃料噴射量を補正する補正量を大きくすることを要旨とする。

【0018】

【発明の効果】請求項1記載の本発明によれば、筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、該圧力検出手段が検出した筒内圧力に基づいて着火時期を予測する着火時期予測手段と、該着火時期予測手段が予測した着火時期に応じて圧縮上死点近傍における燃料噴射量または燃料噴射時期を変更する燃料噴射制御手段と、を備えたことにより、燃料噴射の回数に係わらず外部環境や機関状態変化によるサイクルバラツキがあっても燃焼時期を安定させることができ、高負荷運転領域において圧縮自己着火運転すなわち高効率、クリーンな運転が可能となり、燃費、エミッションが改善できる。

【0019】請求項2記載の本発明によれば、筒内に直接燃料を噴射する燃料直噴装置を備え、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切り替え可能な内燃機関において、筒内圧力を検出する圧力検出手段と、圧縮自己着火燃焼運転時に少なくとも1回の燃料噴

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射を圧縮上死点近傍に行うとともに、前記圧縮上死点近傍の燃料噴射時期以前に前記圧力検出手段が検出した筒内圧力に応じて、燃料噴射制御手段が該サイクルの圧縮上死点近傍の燃料噴射量または燃料噴射時期を変更するようにしたので、各サイクルの燃焼時期を常に目標時期となるように最適に制御することが可能となり、ノッキング及び燃焼安定度悪化を防止し、より高負荷運転領域において圧縮自己着火運転すなわち高効率、クリーンな運転が可能となり、燃費、エミッションを改善することができるという効果がある。

【0020】請求項3記載の本発明によれば、請求項2記載の発明の効果に加えて、前記圧力検出手段が検出した筒内圧力に基づいて燃料の予反応時期を検出する予反応検出手段を備え、前記燃料噴射制御手段は、1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を圧縮上死点から進角した時期に行い、2回目の燃料噴射を圧縮上死点近傍に行い、前記予反応検出手段が検出した予反応時期に応じて、2回目の燃料噴射量または燃料噴射時期を変更するようにしたので、サイクルバラツキに対する燃焼時期の変化を精度良く予測することが可能となり、燃焼時期の更なる遅角が実現でき、より高負荷運転領域において圧縮自己着火運転すなわち高効率、クリーンな運転が可能となり、燃費、エミッションを更に改善できるという効果がある。

【0021】請求項4記載の本発明によれば、請求項2または請求項3記載の発明の効果に加えて、排気上死点近傍で吸気弁及び排気弁が共に閉じている密閉期間を有するように吸排気弁の開閉時期を変更可能な可変動弁装置を備え、1サイクル中に2回に分けて燃料噴射を行い、1回目の燃料噴射を前記密閉期間中に行うようにしたので、密閉期間中の圧縮による高温高圧のために1回目に噴射した燃料の改質が進み、未燃燃料を更に低減できる。また1回目に噴射した燃料の予反応時期が進角するため、燃焼時期の制御がより容易になる。

【0022】請求項5記載の本発明によれば、請求項3または請求項4記載の発明の効果に加えて、前記予反応検出手段が検出した予反応時期が設定値よりも遅角している場合には2回目の燃料噴射時期を補正量分進角するか燃料噴射量を補正量分増量し、予反応時期が設定値よりも進角している場合には2回目の燃料噴射時期を補正量分遅角するか或いは燃料噴射量を補正量分減量するようにしたので、筒内状態のサイクルバラツキにより予反応の進展にバラツキが発生した場合においても、圧縮上死点付近の燃料噴射時期を制御することによって、燃焼時期補正する所定量を大きくすることとしたため、高負荷運転を狙って、燃焼時期を圧縮上死点から十分に遅角することが可能となり、高負荷運転領域において圧縮自己着火運転すなわち高効率、クリーンな運転が可能となり、燃費、エミッションが改善できる。

【0023】請求項6記載の本発明によれば、請求項5

記載の発明の効果に加えて、運転条件に応じて目標燃焼時期を算出する目標燃焼時期算出手段を備え、算出された目標燃焼時期が圧縮上死点から遅角している程、前記圧縮上死点付近の燃料噴射時期または燃料噴射量を補正する補正量を大きくするようにしたので、目標燃焼時期に応じて補正量を変更できるようになり、より正確な燃焼時期制御を行うことができるという効果がある。

【0024】

【発明の実施の形態】以下、図面に基ついて本発明の実施の形態について説明する。図1は本発明に係る内燃機関の燃焼制御装置をガソリンエンジンに適用した第1の実施形態の構成を示すシステム構成図である。

【0025】本実施形態においては、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼とを切換可能となっている。さらに圧縮自己着火燃焼時には、燃料を2回に分けて噴射し、筒内圧力を検出することにより1回目に噴射した燃料の予反応時期を検出し、この検出された予反応時期に応じて2回目の燃料噴射時期を補正することによって、燃焼時期を遅角した高負荷運転時においても燃焼を安定させることが特徴である。

【0026】図中のエンジン本体10は、吸気ポート11、排気ポート12、ピストン13、吸気バルブ14、排気バルブ15、燃料噴射装置16、点火プラグ17、筒内圧力センサ18、クランク角センサ19を備えている。

【0027】このエンジン本体10を制御する電子制御装置（以下、ECUと略す）1は、運転条件に応じて圧縮自己着火燃焼と火花点火燃焼のいずれかの燃焼方式で運転を行うかを判定する燃焼パターン判定部2と、火花点火燃焼運転時の燃焼パラメータを制御する火花点火燃焼制御部3と、圧縮自己着火燃焼運転時の燃焼制御パラメータを制御する自己着火燃焼制御部4と、圧縮自己着火燃焼運転時に燃焼の予反応を検出する予反応検出部5と、予反応検出部5が検出した予反応時期に応じて燃料噴射量または燃料噴射時期を制御する燃料噴射制御部6とを備えている。

【0028】尚、ECU1の構成要素は、燃焼パターン判定部2、火花点火燃焼制御部3、自己着火燃焼制御部4、予反応検出部5、燃料噴射制御部6はハードワイヤードの論理回路で構成することもできるが、本実施形態では、マイクロコンピュータのプログラムとして実現されている。

【0029】またECU1は、クランク角センサ19が検出したエンジン回転信号、及びアクセル開度センサ（図示せず）が検出したアクセル開度信号（負荷）に基づいて、運転条件を判定し、燃料噴射量、点火時期を算出する。そして、この算出結果に基づき、燃料噴射装置16、点火プラグ17に信号を送る。

【0030】このような構成のもと、本発明では、図2に示すような、中低負荷及び中回転数以下の特定の運転

条件において圧縮自己着火燃焼を行い、高負荷または高回転数域においては火花点火燃焼を行う。

【0031】次に、本実施形態の動作について説明する。図3は、空燃比に対する自己着火燃焼が成立する範囲を示すものである。空燃比をリーンにしていくと燃焼安定度が悪化し、機関のトルク変動が大きくなる。このため、内燃機関として設計値、またはこの内燃機関を搭載し車両の性格等として許容できる安定度限界が安定度限界値 S_{th} となる空燃比 A/F_L がリーン限界となる。

【0032】一方、空燃比をリッチにしていくと、ノッキング強度が増大する。これによりノッキング限界 N_{th} における空燃比 A/F_R がリッチ限界となる。従って、安定度限界 A/F_L とノッキング限界空燃比 A/F_R で囲まれる空燃比領域が自己着火燃焼成立範囲となる。このように、自己着火は限られた空燃比範囲でしか成立しない。尚、ここではガスと燃料の割合を示す指標として空燃比 A/F を例に説明した。残留ガスあるいは EGR ガスが含まれる場合についても同様の傾向を示し、この際には横軸は新気と既燃ガスを合わせたトータルのガス量と燃料量割合 G/F となる。

【0033】従って、図4に従来技術における圧縮自己着火燃焼運転範囲を示す。図からわかるように従来技術においては、圧縮自己着火燃焼運転範囲はきわめて狭い範囲に留まっている。

【0034】図5に燃焼時期を変化させた場合の筒内圧力及び熱発生燃焼波形を示す。実線の波形は圧縮上死点直後の燃焼時期による波形であり、破線の波形は燃焼時期を圧縮上死点から遅角した波形である。燃焼時期を遅角すると、筒内圧力の変化は緩やかになる。これはピストン下降時に燃焼が行われるため、燃焼室容積の増大が燃焼温度による圧力上昇の一部を打消し、圧力変化が抑制されるためである。

【0035】図6に燃焼時期を変化させた場合のクランク角当たりの筒内圧力変化率の最大値 $[dP/d\theta]_{max}$ と熱効率とを示す。ノッキングの発生し易さの尺度となる筒内圧力変化率の最大値は、燃焼時期が圧縮上死点直前で最大となり、燃焼時期を圧縮上死点から遅角するにつれて前記最大値 $[dP/d\theta]_{max}$ が低減する。また熱効率は燃焼時期を圧縮上死点から遅角すると悪化していくものの、遅角量が少ない場合には悪化の程度や極めて緩やかである。

【0036】これは、等容度の低下により時間損失が増加するものの、燃焼圧力及び温度が低下し、冷却損失が低下するためである。すなわち、時間損失と冷却損失が相殺するため、燃焼時期を遅角しても熱効率が悪化しない。従って、ノッキングの原因となる前記筒内圧力変化率の最大値 $[dP/d\theta]_{max}$ を低下して、圧縮自己着火燃焼の運転範囲を高負荷側に拡大するためには、熱効率が低下しない程度に燃焼時期を遅角することが有利である。

【0037】前述したように、筒内の温度は残留 EGR ガスの影響を受けるために、燃焼サイクル毎に僅に異なっている。図7には筒内温度が変化した場合の燃焼波形を示している。図7(a)に示すように、燃焼時期が圧縮上死点付近にある場合には筒内温度にサイクルバラツキが発生した場合においても燃焼波形は安定している。

【0038】これに対して、図7(b)に示すように、燃焼時期を遅角した場合には、筒内温度にサイクルバラツキが発生した場合に燃焼波形が大きく変化してしまう。これは燃焼時期を遅角すると安定度が悪化することを示している。すなわち、燃焼時期を遅角するためには、筒内温度等のサイクルバラツキに対するロバスト性(頑健性)を向上する必要がある。

【0039】第1の実施形態では燃料は2回に分けて噴射している。燃料を2回に分けて噴射することによって、燃料が一度に燃焼を開始し、急激な燃焼となり、ノッキングが発生するのを防止している。1回目の燃料噴射時期は圧縮上死点よりも十分進角している。2回目の燃料噴射時期は圧縮上死点付近としており、この2回目の燃料噴射量または燃料噴射時期を制御することによって、着火時期を制御している。

【0040】ガソリンの燃焼は低温酸化反応であるため、中間生成物ができる予反応を経過した後、最終的な酸化反応である熱炎に至る。筒内に噴射された燃料は酸素と混合して、前記反応を進行していく。この時に、予反応の進展度を見ると、自己着火燃焼の開始時期を予測できる。すなわち、1回目に噴射された燃料の予反応の時期を検出して、その結果に応じて2回目の燃料噴射時期を補正することによって、筒内温度等のバラツキに対するロバスト性を向上できる。

【0041】図8は、本実施形態における燃料噴射時期の制御方法を示すものであり、燃料噴射パルス信号と熱発生とを同じ時間軸で示したものである。図中実線Aは、通常の燃料噴射パルス信号及び通常の熱発生を示す。破線Bは、本発明による制御を行わない場合に、何等かの理由で筒内温度が低下した場合の燃料噴射パルス及び熱発生を示す。一点鎖線Cは、本実施形態の ECU の制御下での筒内温度低下時の燃料噴射パルス及び熱発生を示す。

【0042】いずれの場合でも1回目に噴射された燃料が予反応が開始すると予反応による発熱のために筒内圧力が上昇する。この筒内圧力変化を筒内圧力センサ18により検出する。この筒内圧力センサ信号の変化から予反応検出部5が予反応時期を検出し、検出した予反応時期と目標予反応時期とを比較することによって、予想燃焼時期が目標燃焼時期よりどの程度進角しているか遅角しているかが判定できる。この判定により、予想燃焼時期が進角していれば第2回の燃料噴射時期を遅角し、予想燃焼時期が遅角していれば2回目の燃料噴射時期を進角するように、燃料噴射制御部6が制御する。これによ

り、図8の一点鎖線Cに示すように燃焼時期を目標通りに制御することができる。

【0043】尚、燃料噴射制御部6の制御として、2回目の燃料噴射時期の進角に代えて2回目の燃料噴射量の増量、または2回目の燃料噴射時期の遅角に代えて2回目の燃料噴射量の減量を行っても目標通りの燃焼時期に制御することができるが、若干の燃費悪化やトルク変動を伴う欠点がある。

【0044】次に、図9のフローチャートを参照して本実施形態の制御の流れを詳細に説明する。まず図9の概略的な動作を説明する。運転条件を判定して火花点火燃焼と圧縮自己着火燃焼に分岐する。圧縮自己着火燃焼の運転領域では、1回目の燃料噴射後に筒内圧力を検出し、この筒内圧力の変化に基づいて1回目に噴射された燃料の予反応時期を判断する。そして所定時期に比べて予反応時期が進角していれば、2回目の噴射時期を遅角し、予反応時期が遅角していれば、2回目の噴射時期を進角する。これにより最適な圧縮自己着火時期が得られる。

【0045】図9において、まずステップ10（以下、ステップをSと略す）で、アクセル開度信号、クランク角信号を検出し、S11でエンジン回転数、負荷を算出する。次いで、S12でエンジン回転数と負荷から予め記憶した図2のようなマップを参照して燃焼状態を判断する。

【0046】燃焼状態が火花点火燃焼と判断した場合にはS13に進み、火花点火燃焼の制御を開始する。自己着火燃焼と判断した場合には、S14へ進み圧縮自己着火燃焼の制御を開始する。次いで、S15で圧縮上死点から進角した時期に1回目の燃料噴射を行う。次いで、S16で筒内圧力センサ（図1の符号18）で筒内圧力を検出する。S17で予反応検出部5が筒内圧力に基づいて熱発生量を算出し、予反応時期CTを算出する。次いでS18で図10のマップから2回目の燃料噴射時期IT2を呼び込む。

【0047】次いでS19で予反応時期の妥当性を判断する。すなわち、図11に示すようなマップを検索して得られる目標予反応時期CTAと、算出された予反応時期CTとを比較して、CTがCTAに対して進角しているか、ほぼ等しいか、遅角しているかを判定し、この判定結果により2回目の燃料噴射時期を補正する。

【0048】例えば、予反応時期CTが目標予反応時期CTA- α （例えば $\alpha=1$ ）よりも小さい場合には、予反応時期が進角しているので、S20へ分岐し、2回目の燃料噴射時期IT2をIT2+ β と遅角する。

【0049】予反応時期CTが目標予反応時期CTA+ α （例えば $\alpha=1$ ）よりも大きい場合には、予反応時期が遅角しているので、S21へ分岐し、2回目の燃料噴射時期IT2をIT2- β と進角している。CTA- $\alpha \leq CT \leq CTA + \alpha$ の場合には、2回目噴射時期の調整

は行わずS22へ移る。そして、S22で2回目の燃料噴射を補正した時期に行う。

【0050】図10は、エンジン回転数及び負荷による標準の2回目燃料噴射時期IT2のマップである。エンジン回転数が高くなるに従って、2回目に噴射された燃料の気化や改質のための相対時間が短くなるので噴射時期を進角する。負荷が小さくなるに従って燃料噴射量が少なくなり着火困難となるので、噴射時期を進角している。

【0051】図11は、目標予反応時期CTAのマップである。エンジン回転数が高くなるに従って、燃焼の化学反応のための相対時間が短くなるので目標予反応時期を進角している。負荷が小さくなるに従って燃料噴射量が少なくなり着火困難となるので、目標予反応時期を進角している。

【0052】図12は、運転条件による本実施形態の圧縮自己着火燃焼範囲と従来の圧縮自己着火燃焼範囲を示す。図からわかるように、従来例に比べて、本実施形態では圧縮自己着火燃焼の範囲を高負荷側に大幅に拡大できている。

【0053】次に、本発明の第2の実施形態について説明する。図13は、本発明に係る内燃機関の燃焼制御装置の第2の実施形態の構成を示すシステム構成図である。第2の実施形態の構成は、図1に示した第1の実施形態の構成とほぼ同様であるが、第1の実施形態に対して、吸気弁14及び排気弁15のバルブタイミングを変更する可変バルブタイミング機構20を追加していることが異なる。

【0054】第2の実施形態は、可変バルブタイミング機構20により、火花点火燃焼用のバルブタイミングと圧縮自己着火燃焼用のバルブタイミングとを運転中に切り換え可能であり、圧縮自己着火燃焼中の1回目の燃料噴射を排気行程中に吸排気バルブが共に閉じている密閉時期の行うことを特徴とする。

【0055】図14(a)は火花点火燃焼時のバルブタイミング及びバルブリフト、図14(b)は圧縮自己着火燃焼時の燃料噴射パルス信号、図14(c)は圧縮自己着火燃焼時のバルブタイミング及びバルブリフトをそれぞれ示している。

【0056】圧縮自己着火燃焼時には、排気行程途中で排気行程上死点より早い時期に排気弁を閉じている。また吸気弁が開く時期は上死点から十分に遅角しているため、吸気弁が開く以前に吸排気バルブが共に閉じている密閉時期が存在する。1回目の燃料噴射は前記吸排気バルブが共に閉じている密閉時期に行い、2回目の燃料噴射は圧縮上死点付近で行う。

【0057】排気弁が上死点よりも早い時期に閉じるため、筒内には排気されなかった燃焼後のガスが密閉され圧縮される。もともと高温であった燃焼後のガスはこの圧縮により更に高温になる。このような高温高压の雰囲気

気の筒内に燃料を噴射すると、燃料の改質が進む。その結果、燃料の着火性が改善して、予反応時期が進角する。

【0058】図15に第1実施形態の熱発生時期A（実線表示）と第2実施形態の熱発生時期B（破線表示）を示す。本実施形態では1回目に噴射された燃料の改質が第1実施形態より進んでいるため、予反応の発生時期が進角している。また、1回目に噴射された燃料が改質しており、着火性が向上しているため、2回目の燃料噴射時期も遅角される。

【0059】従って、予反応の検出時期から2回目の燃料噴射時期迄時間が長くなり、第1実施形態に比べてECU 1での演算時間を長くとることができる。その結果、予反応時期の判断及び2回目の燃料噴射時期の制御が精度良く行うことができる。

【0060】また、1回目に噴射された燃料が改質しているため、未燃HCも低減することができる。本第2実施形態の制御の流れは、第1の実施形態の制御フロー図9と同じである。

【0061】次に、第3の実施形態について説明する。第3の実施形態の構成は、図1に示した第1の実施形態の構成と同様である。第3の実施形態は、1サイクル中の燃料噴射を1回として、圧縮上死点付近に行く。また燃料噴射時期の補正は、圧縮上死点付近までの筒内圧力及び温度履歴に基づいて行うことを特徴とする。

【0062】第3実施形態では、燃料を一度に噴射するため、燃焼が急激になり易い傾向を示す。従って、燃焼時期を更に遅角する必要があり燃焼時期を精度良く制御する必要がある。一方、1サイクル当たりの燃料噴射は1回としているため、噴射される燃料の算出は容易であり、空燃比の制御は精度を高く保つことができる。

【0063】図16に第1実施形態の熱発生時期A（実線表示）と第3実施形態の熱発生時期B（破線表示）との比較を示す。第3実施形態では、圧縮上死点付近で燃料噴射が行われるまで、筒内に燃料がないため、予反応は起こらない。従って、第1実施形態のように予反応時期から圧縮上死点付近の燃料噴射時期を補正することはできない。このため、第3実施形態では、あるサンプリング間隔で筒内圧力センサ18が検出した筒内圧力に基づいて筒内温度を求め、筒内圧力及び筒内温度に基づいて着火時期を予測し、この予測された着火時期に応じて圧縮上死点付近の燃料噴射時期を補正することに特徴がある。

【0064】図17は、定容器における温度、圧力に対するガソリン混合気の着火遅れ時間 τ の逆数 $1/\tau$ を示す。着火遅れ時間の逆数 $1/\tau$ が大きい程燃料が着火し易いことを示している。

【0065】また図17中には、圧縮行程中における温度及び圧力の履歴の例を示している。定容器における着火遅れ時間の逆数 $1/\tau$ を利用して、連続的に圧力及び

温度が変化する圧縮自己着火の着火時期を予測することができる。これは、各サイクルの筒内の温度及び圧力の履歴に従って、 $1/\tau$ を積算して $\int 1/\tau dt (=BP)$ 、以下着火指数と呼ぶ)を求めることにより達成される。

【0066】即ち圧縮開始直後から、あるサンプリング間隔(ΔT)で筒内圧力を検出し、この圧力に応じた温度を算出し、これら圧力及び温度から図17のマップを検索して $1/\tau$ を求める。そして、 $BP = \int 1/\tau dt$ 、実際には $\Sigma [(1/\tau) \times \Delta T]$ が着火レベル(=1のある値)に達したときを着火時期と判定できる。

【0067】図18は、各クランク角における $BP = \int 1/\tau dt$ と、熱発生を示す。Aの通常の燃料噴射時期ITに対して、筒内温度が低下したBではBPの値が低くなっている。従って、この状態で通常のITで燃料噴射を行うと着火時期が遅角して燃焼が不安定になる。

【0068】これに対して、BPの値を燃料噴射時期以前の或る判定時期において所定の判定レベルに達しているか否かを判断して、判定レベルに達していない場合、圧縮行程中の噴射時期ITを進角した場合をCに示す。筒内温度が低下して、着火までの反応時間が長くなった分を考慮して、燃料噴射時期ITを補正量 β だけ進角することによって、目標とする時期に圧縮着火燃焼するように制御することができる。

【0069】次に、図19のフローチャートを参照して、第3実施形態の制御の流れを説明する。制御の概略的な流れは第1実施形態のフローチャートである図9と同様である。第1実施形態と異なる点は、S35以下の着火時期予測のための着火指数BPの算出と、その判断結果により圧縮行程中の噴射時期を進角、保持、遅角する点である。

【0070】S35で筒内圧力センサにより筒内圧力Pを検出する。S36で後述するように、筒内圧力Pから筒内温度Tを算出する。次いで、S37で筒内圧力P及び筒内温度Tから、例えば図17の様なマップを検索して着火遅れ時間 τ の逆数 $1/\tau$ を求める。S38で着火指数 $BP = \int 1/\tau dt$ を算出する。S39で着火指数の判断時期か否かを判断し、まだ判断時期でなければ、S35に戻って着火指数BPの積算を続ける。

【0071】判断時期であれば、S40で設定の燃料噴射時期ITを呼び込む。S41で着火指数 $BP = \int 1/\tau dt$ の値とその目標値 γ とのずれを判断する。BPが下限値($\gamma - 0.01$)より小さい場合には、着火時期が遅れると予測し、S42で燃料噴射時期を進角する。

【0072】BPが上限値($\gamma + 0.01$)より大きい場合には、着火時期が進角すると予測し、S43で燃料噴射時期を遅角する。BPの値のずれが目標値 γ から限度内($\gamma - 0.01 \leq BP \leq \gamma + 0.01$)であれば、燃料噴射時期の設定変更は行わない。そしてS44で圧縮行程中の燃料噴射を行う。

【0073】ここで、S36における筒内圧力Pから筒内温度Tを算出する方法について説明する。この算出方法は、燃焼解析と呼ばれる方法であり、以下の3式の連*

$$\text{熱力学の第1法則} \quad dQ = dU + dW \quad \dots (1)$$

$$\text{状態方程式} \quad PV = mRT \quad \dots (2)$$

$$\text{内部エネルギー式} \quad dU = d(m \cdot C_v \cdot T) \quad \dots (3)$$

ここで、Q：投入熱量、U：内部エネルギー、W：仕事、P：筒内圧力、V：容積、m：モル数、R：ガス定数、T：筒内温度、C_v：定容比熱である。

【0075】以上の3式を解くことによって、各クランク角毎のポリトロープ指数が求まり、精度よく筒内温度を予測することができる。この解法は燃焼解析と呼ばれ、当業者にとって公知であり、紙幅も要するので詳細は省略する。

$$T = T_0 \times (V_0 / V)^{(n-1)} \quad \dots (4)$$

ここで、T：筒内温度、V：容積、T₀：初期温度、V₀：初期容積、n：ポリトロープ指数である。

【0078】次に、第4の実施形態について説明する。第4の実施形態の構成は第1の実施形態の構成を示す図1と同じである。第4の実施形態は予反応時期が変化した場合の、圧縮上死点付近の燃料噴射時期の補正量を目標燃焼時期に応じて変えることを特徴とする。このため、本実施形態においては、燃料噴射制御部6の内部に、図20に示すような運転条件に応じた目標燃焼時期BTAのマップと、図21に示すような燃焼時期に応じた燃料噴射時期の補正量βマップを備えている。

【0079】前述したように、筒内温度のサイクルバラツキに対する燃焼のロバスト性は燃焼時期によって変化する。燃焼時期が圧縮上死点から遅角する程、燃焼のロバスト性が低下する。従って、燃焼時期が遅角した場合には、予反応時期が変化した場合の、圧縮上死点付近の燃料噴射時期の補正量を大きくする。その結果、燃焼時期に因らず、燃焼のロバスト性を向上することができる。

【0080】次に、図22のフローチャートを参照して、第4実施形態の制御の流れを説明する。制御の概略的な流れは第1実施形態のフローチャートである図9と同様である。

【0081】第1実施形態と異なる所のみ説明する。S59で目標燃焼時期BTAを例えば図20の様なマップから呼び込む。S60で予反応時期CTを判断し、予反応時期が進角していれば(CT < CTA - α)、S61で補正量βを目標燃焼時期BTAから求め、S62で2回目燃料噴射時期IT2を補正量βだけ遅角する。予反応時期が遅角していれば(CT > CTA + α)、S63で補正量βを目標燃焼時期BTAから求め、S64で2回目燃料噴射時期IT2を補正量βだけ進角する。CTA - α ≤ CT ≤ CTA + αの場合には、2回目噴射時期の調整は行わずS65へ移る。そして、S65で2回目の燃料噴射を補正した時期に行う。

* 立微分方程式を解くことによって筒内温度を算出する。
【0074】

【数1】

$$\dots (1)$$

$$\dots (2)$$

$$\dots (3)$$

※【0076】また筒内温度Tをポリトロープ変化に基づいて求めることもできるが、初期温度T₀を得るための吸気温度センサが必要となり、またサイクル中常に一定のポリトロープ指数nを仮定しているため、精度は若干低下する。以下に、ポリトロープ変化による温度算出式を示す。

【0077】

【数2】

$$\dots (4)$$

【図面の簡単な説明】

【図1】本発明に係る内燃機関の燃焼制御装置の第1の実施形態の構成図である。

【図2】運転条件に対する燃焼パターンを説明する図である。

【図3】自己着火成立範囲を説明する図である。

【図4】従来技術の圧縮自己着火燃焼運転範囲を説明する図である。

【図5】燃焼時期に対する燃焼波形を説明する図である。

【図6】燃焼時期に対する筒内圧力上昇率の最大値〔dP/dθ_{max}〕及び熱効率を説明する図である。

【図7】燃焼時期に対する燃焼のロバスト性を説明する図である。

【図8】第1実施形態の燃焼安定性を説明する図である。

【図9】第1実施形態の制御フローチャート図である。

【図10】エンジン回転数及び負荷に対する2回目の燃料噴射時期(IT2)マップである。

【図11】エンジン回転数及び負荷に対する目標予反応時期(CTA)マップである。

【図12】第1実施形態の圧縮自己着火燃焼運転範囲を説明する図である。

【図13】第2実施形態の構成図である。

【図14】第2実施形態のバルブタイミングを説明する図である。

【図15】第2実施形態の熱発生を説明する図である。

【図16】第3実施形態の熱発生を説明する図である。

【図17】温度、圧力に対する着火遅れ時間τの逆数1/τを説明する図である。

【図18】第3実施形態の燃焼安定性を説明する図である。

【図19】第3実施形態の制御フローチャート図である。

【図20】エンジン回転数及び負荷に対する目標燃焼時

期を説明する図である。

【図21】目標燃焼時期に対する燃料噴射時期(IT)の補正量 β を説明する図である。

【図22】第4実施形態の制御フローチャート図である。

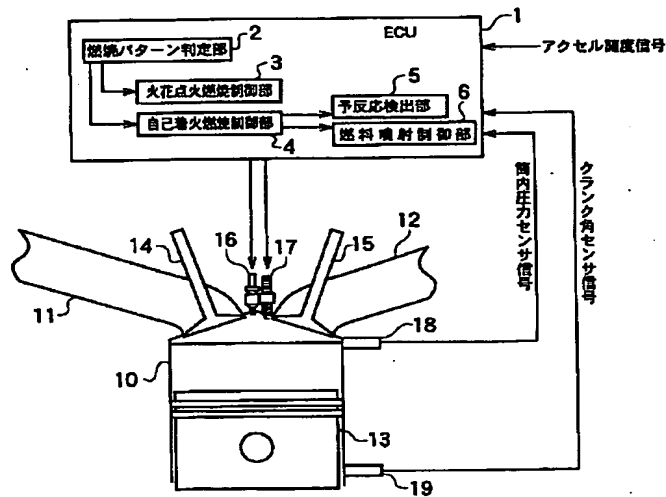
【符号の説明】

- 1 ECU
- 2 燃焼パターン判定部
- 3 火花点火燃焼制御部
- 4 自己着火燃焼制御部
- 5 予反応検出部
- 6 燃料噴射制御部

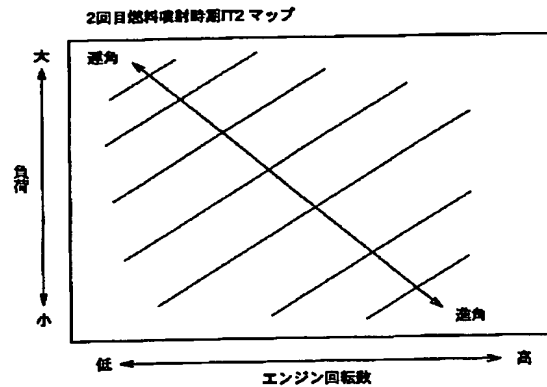
- * 10 エンジン本体
- 11 吸気ポート
- 12 排気ポート
- 13 ピストン
- 14 吸気バルブ
- 15 排気バルブ
- 16 燃料噴射装置
- 17 点火プラグ
- 18 筒内圧力センサ
- 10 19 クランク角センサ
- 20 可変バルブタイミング機構

*

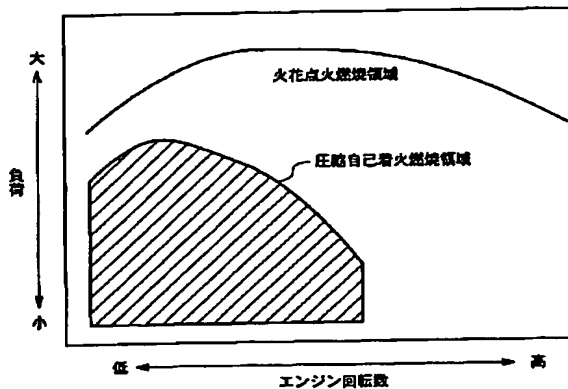
【図1】



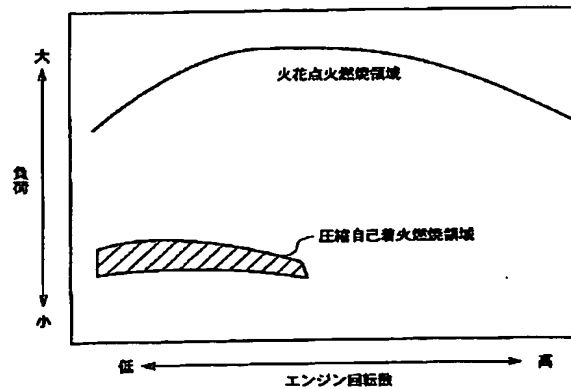
【図10】



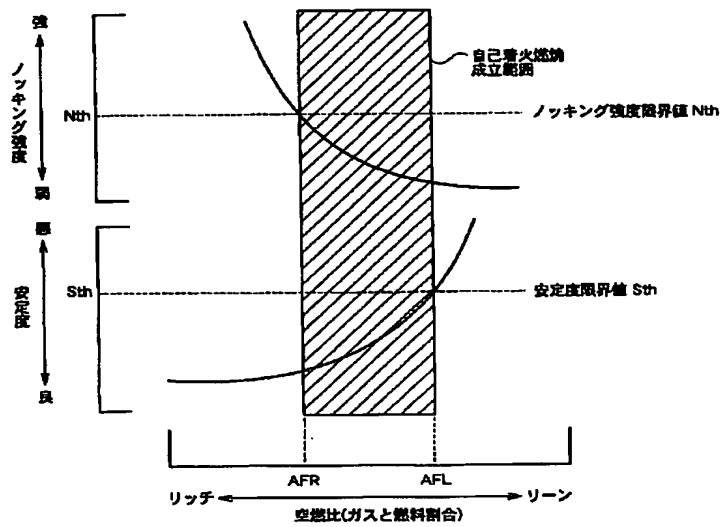
【図2】



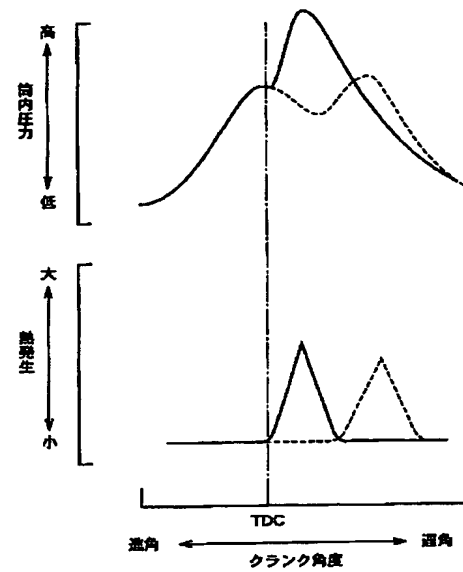
【図4】



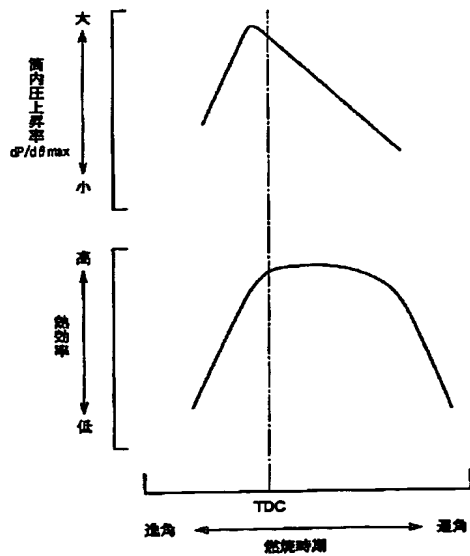
【図3】



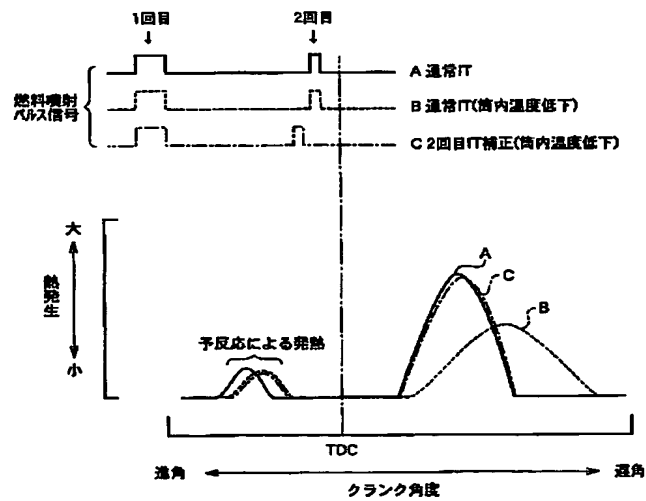
【図5】



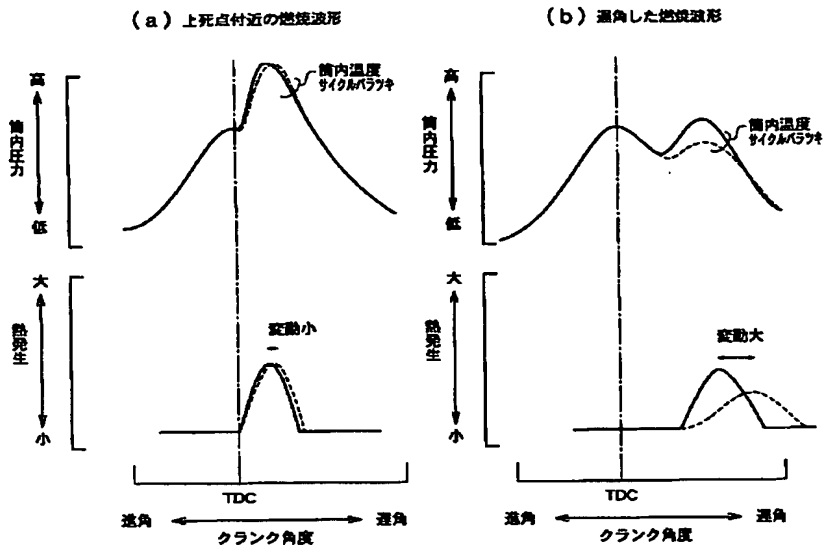
【図6】



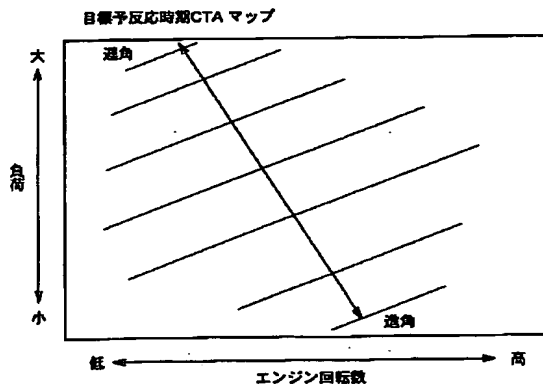
【図8】



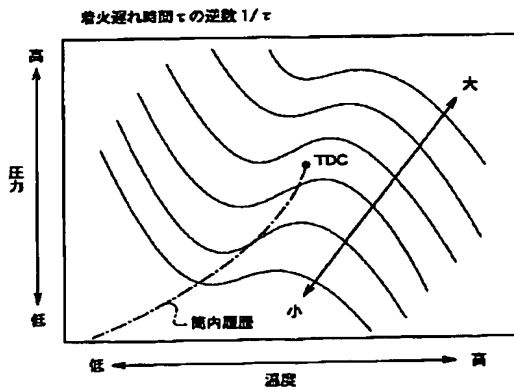
【図7】



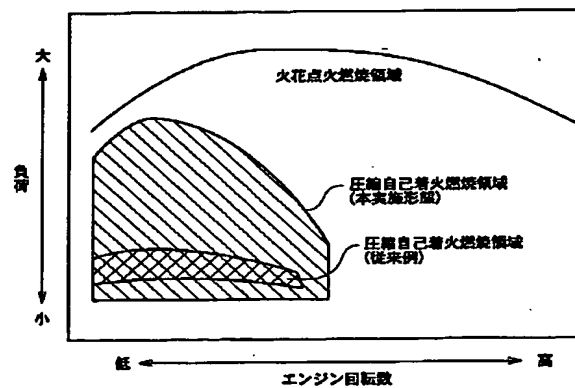
【図11】



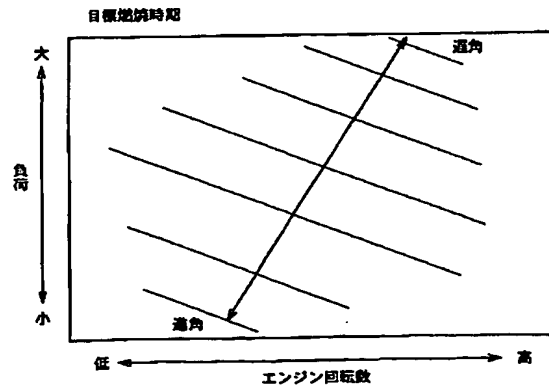
【図17】



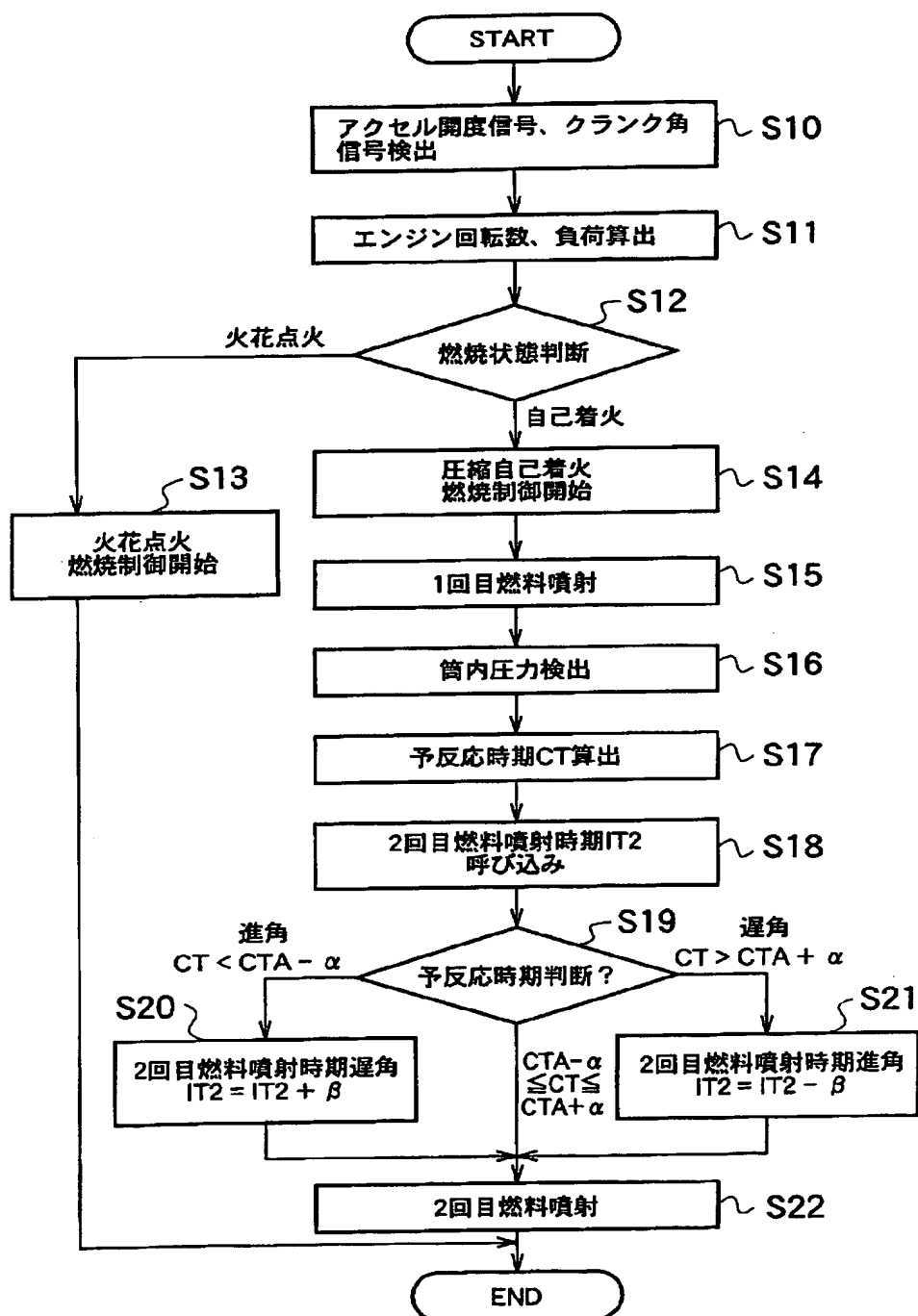
【図12】



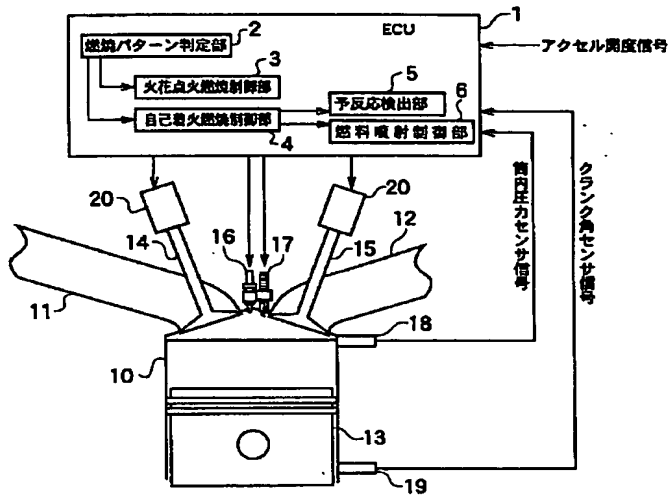
【図20】



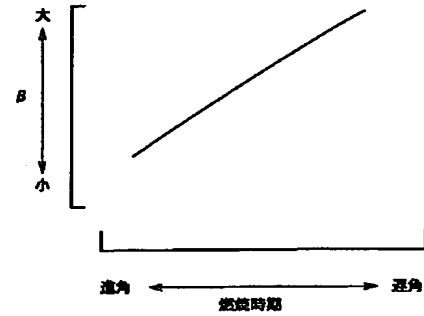
【図9】



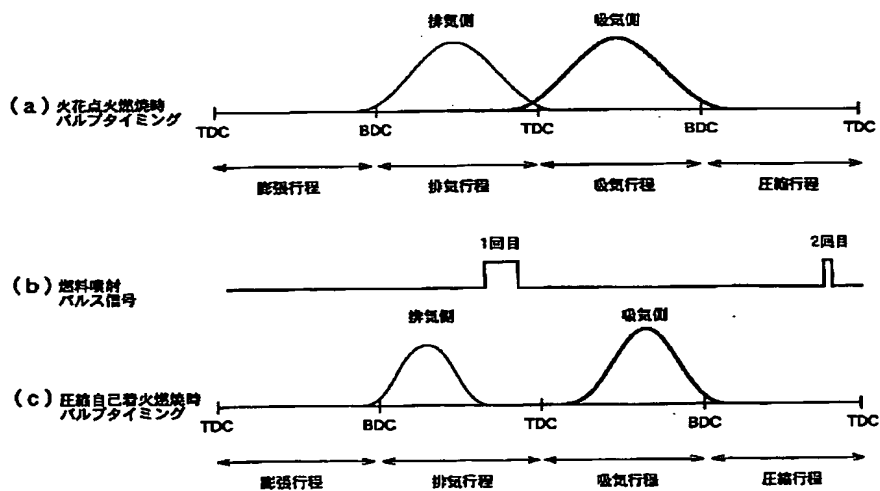
【図13】



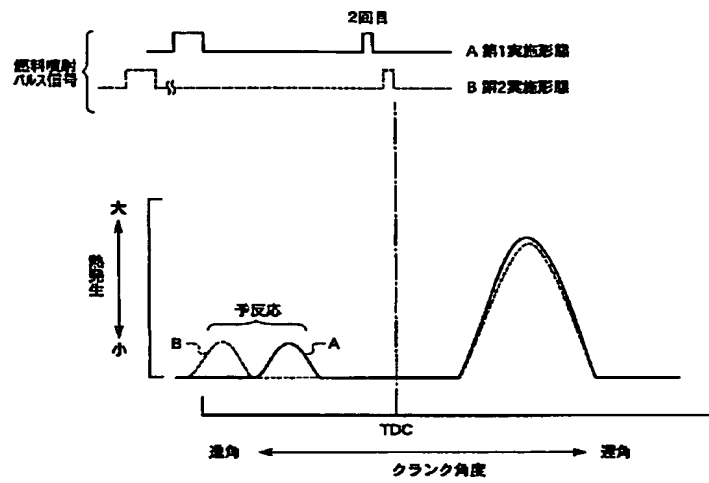
【図21】



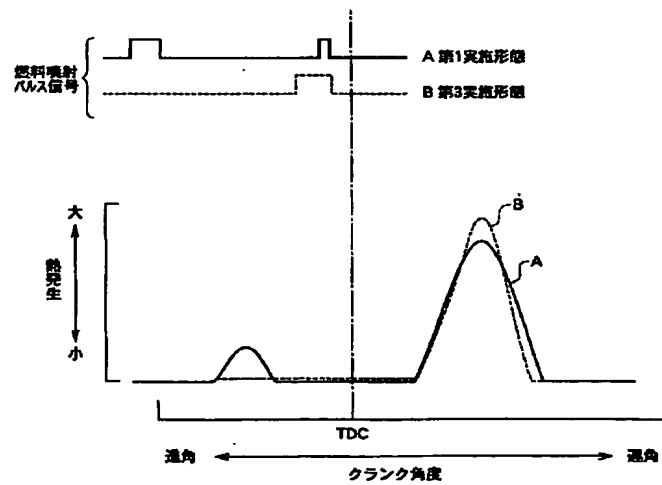
【図14】



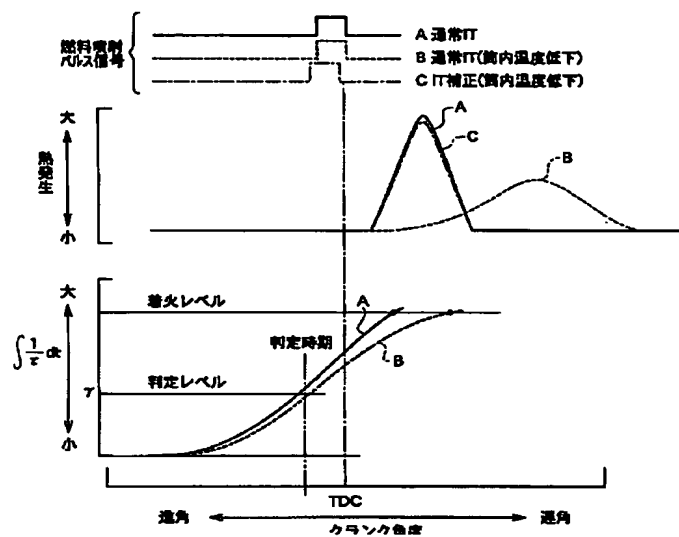
【図15】



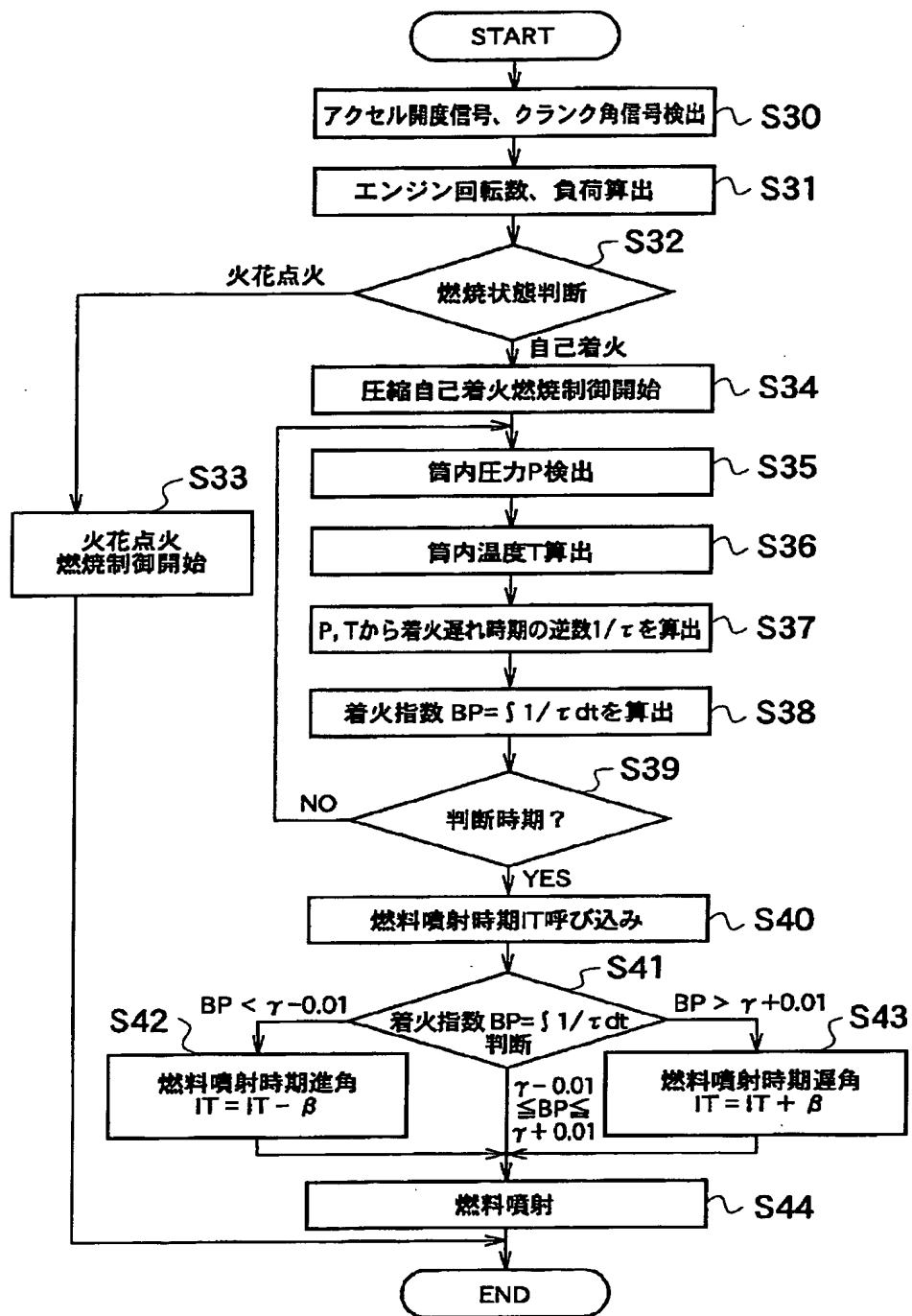
【図16】



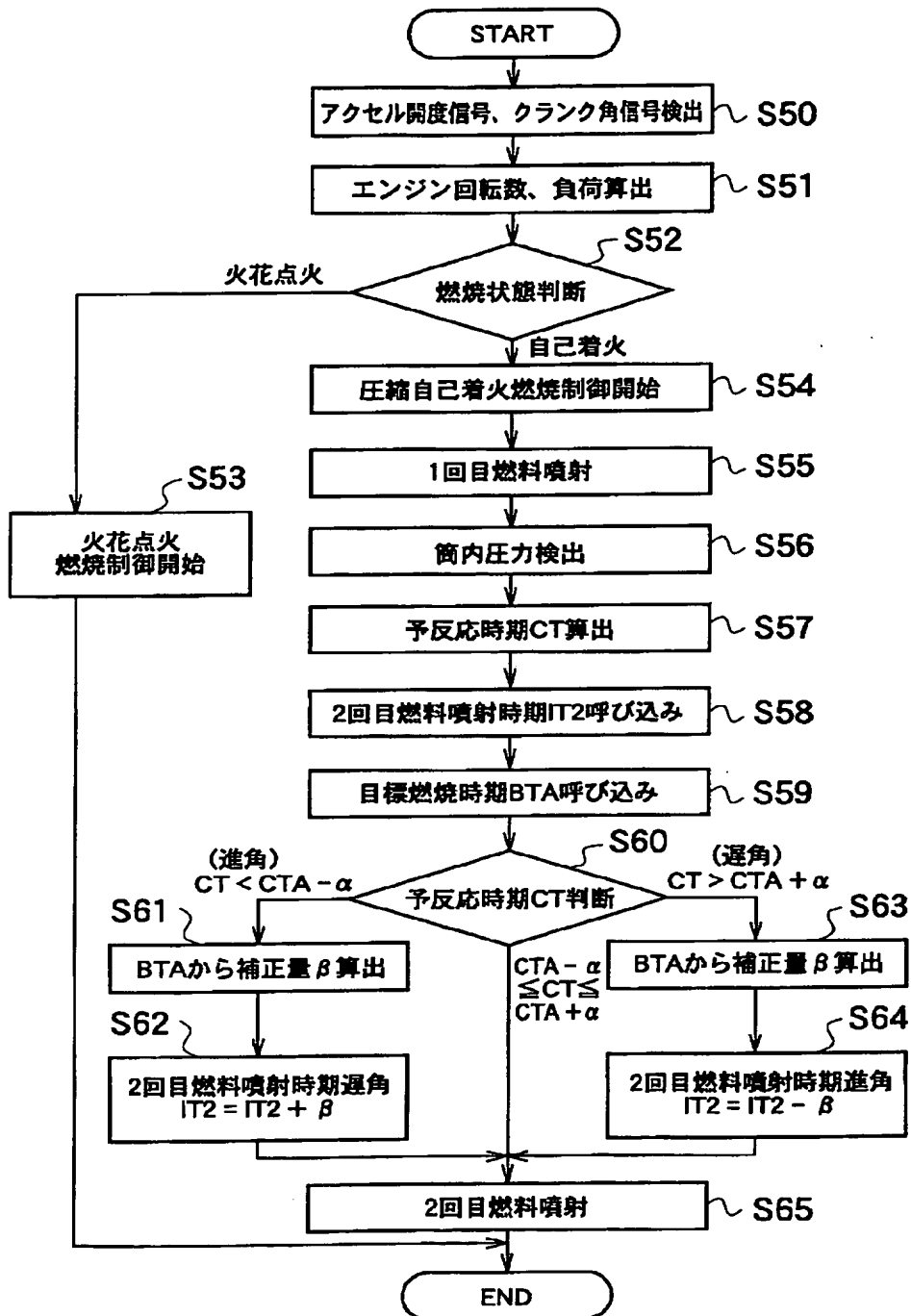
【図18】



【図19】



【図22】



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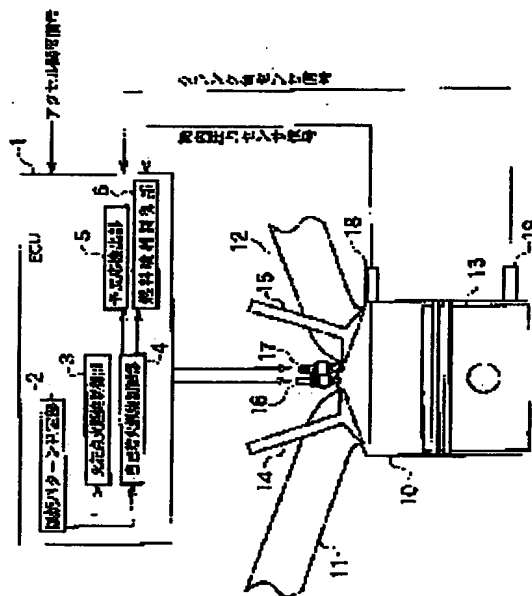
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(54) COMBUSTION CONTROL DEVICE OF INTERNAL COMBUSTION ENGINE

(57)Abstract:

PROBLEM TO BE SOLVED: To avoid knocking and combustion instability, and expand an operation range by compression self-ignition combustion to the high load side.

SOLUTION: A combustion pattern judging part 2 judges in which combustion method of compression self-ignition combustion and spark ignition combustion operation is performed according to an operation condition. A spark ignition combustion control part 3 controls a combustion parameter at spark ignition combustion operation time, and a self-ignition combustion control part 4 controls a combustion parameter at compression self-ignition combustion operation time. A prereaction detecting part 5 detects prereaction of combustion at compression self-ignition combustion operation time on the basis of a detecting signal of a cylinder internal pressure sensor 18, and a fuel injection control part 6 controls a fuel injection quantity or the fuel injection timing according to prereaction time detected by the prereaction detecting part 5 to set the combustion timing as the target timing.



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CLAIMS

[Claim(s)]

[Claim 1] Have in a cylinder fuel direct injection equipment which injects a direct fuel, and compressed self-ignition combustion and jump-spark-ignition combustion are set to a switchable internal combustion engine according to a service condition. A pressure detection means to detect cylinder internal pressure, and a firing stage prediction means to predict a firing stage based on the cylinder internal pressure which this pressure detection means detected, The combustion control system of the internal combustion engine characterized by having the fuel-injection control means which changes fuel oil consumption or fuel injection timing according to the firing stage which this firing stage prediction means predicted. [/ near the compression top dead center]

[Claim 2] Have in a cylinder fuel direct injection equipment which injects a direct fuel, and compressed self-ignition combustion and jump-spark-ignition combustion are set to a switchable internal combustion engine according to a service condition. While performing at least one fuel injection near the compression top dead center at the time of a pressure detection means to detect cylinder internal pressure, and compressed self-ignition combustion operation The combustion control system of the internal combustion engine characterized by having the fuel-injection control means which changes the fuel oil consumption or fuel injection timing near the compression top dead center of this cycle according to the cylinder internal pressure which said pressure detection means detected before the fuel injection timing near [said] the compression top dead center.

[Claim 3] It has a reaction detection means beforehand. the cylinder internal pressure which said pressure detection means detected -- being based -- a fuel -- a reaction stage is detected beforehand -- said fuel-injection-timing control means Perform fuel injection in 2 steps into 1 cycle, and it carries out at the stage which carried out the tooth lead angle of the 1st fuel injection from the compression top dead center. The combustion control system of the internal combustion engine according to claim 2 which performs 2nd fuel injection near the compression top dead center, and is characterized by said thing [changing the 2nd fuel oil consumption or fuel injection timing according to a reaction stage beforehand] to which the reaction detection means detected beforehand.

[Claim 4] The combustion control system of the internal combustion engine according to claim 2 or 3 characterized by having the adjustable moving valve mechanism which can change the closing motion stage of an induction-exhaust valve so that it may have the sealing period which both the inlet valve and the exhaust valve have closed near the exhaust air top dead center, performing fuel injection in 2 steps into 1 cycle, and performing 1st fuel injection during said sealing period.

[Claim 5] The combustion control system of the internal combustion engine according to claim 3 or 4 characterized by carrying out the amount part angle of delay of amendments of the 2nd fuel injection timing, or decreasing the quantity of fuel oil consumption by the amount of amendments when the amount part tooth lead angle of amendments of the 2nd fuel injection timing is carried out, or the quantity of fuel oil consumption is increased by the amount of amendments when [said / which the reaction detection means detected beforehand] the reaction stage has carried out the angle of delay more nearly beforehand than the set point, and the reaction stage has carried out the tooth lead angle more

nearly beforehand than the set point.

[Claim 6] The combustion control system of the internal combustion engine according to claim 5 characterized by enlarging the amount of amendments which amends the fuel injection timing or fuel oil consumption near [said] a compression top dead center, so that it has a combustion stage calculation means to compute a target combustion stage according to a service condition and the computed target combustion stage is carrying out the angle of delay from the compression top dead center.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] By starting the internal combustion engine which can switch jump-spark-ignition combustion and compressed self-ignition combustion according to a service condition, especially optimizing 1 time or 2 times of fuel injection timing at the time of compressed self-ignition combustion, this invention stabilizes a combustion stage and relates to the combustion control system of the internal combustion engine which performs compressed self-ignition combustion by the large operating range.

[0002]

[Description of the Prior Art] In order to improve the thermal efficiency of a gasoline engine, while reducing a pumping loss by Lean-izing gaseous mixture, the technique of enlarging the ratio of specific heat of working medium, and improving a theoretical thermal efficiency is known. However, with the conventional jump-spark-ignition engine, if an air-fuel ratio is Lean-ized, a combustion period will delay and combustion stability will get worse. For this reason, there is a limitation in Lean-ization of an air-fuel ratio.

[0003] The cycle engine which premixing compressed self-ignition combustion is made to cause as it considers as the technique which Lean-izes an air-fuel ratio and is in JP,7-71279,A is indicated like 2 line, avoiding aggravation of such combustion stability. In premixing compressed self-ignition combustion, since a combustion reaction occurs from two or more locations of a combustion chamber, when an air-fuel ratio Lean-izes, the combustion stabilized also in the Lean air-fuel ratio is attained, without a combustion period delaying compared with jump spark ignition. Moreover, combustion temperature falls for Lean and an air-fuel ratio can also reduce NOx substantially.

[0004]

[Problem(s) to be Solved by the Invention] However, in the 1st conventional example, since [usual] about two lines was considered as the cycle engine configuration, there are no intake valve and exhaust air bulb which control a gas exchange, the blow by of unburned gas occurred, and fuel consumption was getting worse. Moreover, since an expansion stroke turned into an expansion exhaust stroke which exhausts in the second half from the need of performing a gas exchange and work by expansion of combustion gas was not fully able to be taken out, there was a trouble that heavy load operation was difficult.

[0005] On the other hand, self-ignition combustion is strongly influenced of an air-fuel ratio. For example, when heavy load operation is considered and an air-fuel ratio is made deep, the fuel quantity which causes a combustion reaction increases, combustion becomes intense, and knocking is caused. For this reason, the trouble [count / of combustion] that one usual operation according to self-ignition combustion with a heavy load with a cycle engine about four lines was difficult was in two revolutions.

[0006] In order to expand the load range where knocking is avoided and compressed self-ignition combustion is materialized, it is effective to carry out the angle of delay of the combustion stage from a compression top dead center. If the angle of delay of the combustion stage is carried out, since

combustion will be performed at the time of piston descent, cylinder internal pressure $[dP/dR/C \text{ theta}]$ max leading to knocking can be reduced.

[0007] However, since the time amount to which the pressure in a cylinder and temperature are kept high decreases when the angle of delay of the combustion stage is carried out, the robustness over the cycle variation of the excess air factor λ in a cylinder and temperature falls, and there is a trouble that combustion becomes instability.

[0008] For example, although residual EGR gas is influenced of the combustion condition of a before cycle, when the temperature of residual EGR gas changes, the temperature in the cylinder of degree cycle will also change. Therefore, when the stability of combustion was considered, it was difficult to fully carry out the angle of delay of the combustion stage from a compression top dead center.

[0009] As 2nd conventional technique, as it is in JP,7-217478,A, the fuel injection equipment of the cylinder-injection-of-fuel type spark-ignition engine which supplies a fuel in a cylinder in 2 steps into 1 cycle is indicated. This conventional example supplies the fuel in 2 steps, in order to avoid a spark-ignition engine's knocking. However, in the 2nd conventional example, control of fuel injection timing is omitted in consideration of λ in a cylinder, and the cycle variation of a temperature condition. Therefore, since the stability of combustion got worse as mentioned above when this is applied to compressed self-ignition combustion, heavy load operation was difficult.

[0010] This invention is what took the example by this trouble, and the object is offering the combustion control system of the internal combustion engine which can expand the operating range by compressed self-ignition combustion to a heavy load side, avoiding knocking and combustion instability.

[0011] Moreover, the object of this invention expands the operating range by compressed self-ignition combustion, and improves fuel consumption and emission, and thermal efficiency is to offer a clean high internal combustion engine.

[0012]

[Means for Solving the Problem] In order that invention according to claim 1 may solve said technical problem, it is equipped with the fuel direct injection equipment which injects a direct fuel in a cylinder, and sets compressed self-ignition combustion and jump-spark-ignition combustion to a switchable internal combustion engine according to a service condition. A pressure detection means to detect cylinder internal pressure, and a firing stage prediction means to predict a firing stage based on the cylinder internal pressure which this pressure detection means detected, Let it be a summary to have had the fuel-injection control means which changes fuel oil consumption or fuel injection timing according to the firing stage which this firing stage prediction means predicted. [/ near the compression top dead center]

[0013] In order that invention according to claim 2 may solve said technical problem, it is equipped with the fuel direct injection equipment which injects a direct fuel in a cylinder, and sets compressed self-ignition combustion and jump-spark-ignition combustion to a switchable internal combustion engine according to a service condition. While performing at least one fuel injection near the compression top dead center at the time of a pressure detection means to detect cylinder internal pressure, and compressed self-ignition combustion operation Let it be a summary to have had the fuel-injection control means which changes the fuel oil consumption or fuel injection timing near the compression top dead center of this cycle according to the cylinder internal pressure which said pressure detection means detected before the fuel injection timing near [said] the compression top dead center.

[0014] Invention according to claim 3 is set to the combustion control system of an internal combustion engine according to claim 2 in order to solve said technical problem. It has a reaction detection means beforehand. the cylinder internal pressure which said pressure detection means detected -- being based -- a fuel -- a reaction stage is detected beforehand -- said fuel-injection control means Perform fuel injection in 2 steps into 1 cycle, and it carries out at the stage which carried out the tooth lead angle of the 1st fuel injection from the compression top dead center. 2nd fuel injection is performed near the compression top dead center, and let beforehand said thing [changing the 2nd fuel oil consumption or fuel injection timing] to which the reaction detection means detected beforehand be a summary according to a reaction stage.

[0015] Invention according to claim 4 makes it a summary to have the adjustable moving valve mechanism which can change the closing motion stage of an induction-exhaust valve so that it may have the sealing period which both the inlet valve and the exhaust valve have closed near the exhaust air top dead center, to perform fuel injection in 2 steps into 1 cycle, and to perform 1st fuel injection during said sealing period in the combustion control system of an internal combustion engine according to claim 2 or 3 in order to solve said technical problem.

[0016] Invention according to claim 5 is set to the combustion control system of an internal combustion engine according to claim 3 or 4 in order to solve said technical problem. When [said / which the reaction detection means detected beforehand] the reaction stage has carried out the angle of delay more nearly beforehand than the set point, carry out the amount part tooth lead angle of amendments of the 2nd fuel injection timing, or the quantity of fuel oil consumption is increased by the amount of amendments. When the reaction stage has carried out the tooth lead angle more nearly beforehand than the set point, let it be a summary to carry out the amount part angle of delay of amendments of the 2nd fuel injection timing, or to decrease the quantity of fuel oil consumption by the amount of amendments.

[0017] Invention according to claim 6 makes it a summary to enlarge the amount of amendments which amends the fuel injection timing or fuel oil consumption near [said] a compression top dead center, so that it has a target combustion stage calculation means to compute a target combustion stage according to a service condition and the computed target combustion stage is carrying out the angle of delay from the compression top dead center in the combustion control system of an internal combustion engine according to claim 5, in order to solve said technical problem.

[0018]

[Effect of the Invention] According to this invention according to claim 1, have in a cylinder fuel direct injection equipment which injects a direct fuel, and compressed self-ignition combustion and jump-spark-ignition combustion are set to a switchable internal combustion engine according to a service condition. A pressure detection means to detect cylinder internal pressure, and a firing stage prediction means to predict a firing stage based on the cylinder internal pressure which this pressure detection means detected, By having had the fuel-injection control means which changes fuel oil consumption or fuel injection timing according to the firing stage which this firing stage prediction means predicted [/ near the compression top dead center] Even if there is cycle variation by the external environment or the engine change of state irrespective of the count of fuel injection, a combustion stage can be stabilized, in a heavy load operating range, compressed self-ignition operation, i.e., efficient and clean operation, is attained, and fuel consumption and emission can be improved.

[0019] According to this invention according to claim 2, have in a cylinder fuel direct injection equipment which injects a direct fuel, and compressed self-ignition combustion and jump-spark-ignition combustion are set to a switchable internal combustion engine according to a service condition. While performing at least one fuel injection near the compression top dead center at the time of a pressure detection means to detect cylinder internal pressure, and compressed self-ignition combustion operation Since the fuel oil consumption or fuel injection timing near the compression top dead center whose fuel-injection control means is this cycle was changed according to the cylinder internal pressure which said pressure detection means detected before the fuel injection timing near [said] the compression top dead center It becomes possible to control the combustion stage of each cycle the optimal so that a target stage always comes. Knocking and combustion stability aggravation are prevented, compressed self-ignition operation, i.e., efficient and clean operation, is attained more in a heavy load operating range, and it is effective in fuel consumption and emission being improvable.

[0020] According to this invention according to claim 3, it adds to an effect of the invention according to claim 2. It has a reaction detection means beforehand. the cylinder internal pressure which said pressure detection means detected -- being based -- a fuel -- a reaction stage is detected beforehand -- said fuel-injection control means Perform fuel injection in 2 steps into 1 cycle, and it carries out at the stage which carried out the tooth lead angle of the 1st fuel injection from the compression top dead center. the 2nd fuel injection -- a near compression top dead center -- carrying out -- said -- the reaction detection means detected beforehand, since the 2nd fuel oil consumption or fuel injection timing was

beforehand changed according to the reaction stage It becomes possible to predict change of the combustion stage to cycle variation with a sufficient precision. The further angle of delay of a combustion stage can be realized, compressed self-ignition operation, i.e., efficient and clean operation, is attained more in a heavy load operating range, and it is effective in fuel consumption and emission being further improvable.

[0021] According to this invention according to claim 4, it adds to an effect of the invention according to claim 2 or 3. It has the adjustable moving valve mechanism which can change the closing motion stage of an induction-exhaust valve so that it may have the sealing period which both the inlet valve and the exhaust valve have closed near the exhaust air top dead center. Since fuel injection is performed in 2 steps into 1 cycle and it was made to perform 1st fuel injection during said sealing period, refining of the fuel injected to the 1st time for the elevated-temperature high voltage by the compression during a sealing period progresses, and an unburnt fuel can be reduced further. Moreover, in order that [of the fuel injected to the 1st time] a reaction stage may carry out a tooth lead angle beforehand, control of a combustion stage becomes easier.

[0022] According to this invention according to claim 5, it adds to an effect of the invention according to claim 3 or 4. When [said / which the reaction detection means detected beforehand] the reaction stage has carried out the angle of delay more nearly beforehand than the set point, carry out the amount part tooth lead angle of amendments of the 2nd fuel injection timing, or the quantity of fuel oil consumption is increased by the amount of amendments. Since the amount part angle of delay of amendments of the 2nd fuel injection timing is carried out or the quantity of fuel oil consumption was decreased by the amount of amendments when the reaction stage had carried out the tooth lead angle more nearly beforehand than the set point It writes enlarging the specified quantity which carries out combustion stage amendment by controlling the fuel injection timing near a compression top dead center when variation occurs in progress of a reaction beforehand by the cycle variation of the condition in a cylinder. Heavy load operation is aimed at, it becomes possible to fully carry out the angle of delay of the combustion stage from a compression top dead center, compressed self-ignition operation, i.e., efficient and clean operation, is attained in a heavy load operating range, and fuel consumption and emission can be improved.

[0023] According to this invention according to claim 6, it adds to an effect of the invention according to claim 5. It has a target combustion stage calculation means to compute a target combustion stage according to a service condition. Since it was made to enlarge the amount of amendments which amends the fuel injection timing or fuel oil consumption near [said] a compression top dead center so that the computed target combustion stage was carrying out the angle of delay from the compression top dead center The amount of amendments can be changed now according to a target combustion stage, and it is effective in the ability to perform more exact combustion stage control.

[0024]

[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained based on a drawing. Drawing 1 is system configuration drawing showing the configuration of the 1st operation gestalt which applied the combustion control system of the internal combustion engine concerning this invention to the gasoline engine.

[0025] In this operation gestalt, it is switchable in compressed self-ignition combustion and jump-spark-ignition combustion according to a service condition. A reaction stage is detected beforehand and it is the description to stabilize combustion at the time of heavy load operation of the fuel which furthermore injected the fuel in 2 steps at the time of compressed self-ignition combustion, and was injected to the 1st time by detecting cylinder internal pressure which carried out the angle of delay of the combustion stage by [this / that amends the 2nd fuel injection timing according to a reaction stage beforehand] having been detected.

[0026] The engine 10 in drawing is equipped with an inlet port 11, an exhaust port 12, a piston 13, an intake valve 14, the exhaust air bulb 15, the fuel injection equipment 16, the ignition plug 17, the cylinder internal pressure sensor 18, and the crank angle sensor 19.

[0027] The electronic control (it abbreviates to ECU hereafter) 1 which controls this engine 10 The

combustion pattern judging section 2 which judges whether it operates according to a service condition by either combustion system of compressed self-ignition combustion and jump-spark-ignition combustion, The jump-spark-ignition combustion-control section 3 which controls the combustion parameter at the time of jump-spark-ignition combustion operation, The self-ignition combustion-control section 4 which controls the combustion-control parameter at the time of compressed self-ignition combustion operation, It has the fuel-injection control section 6 of combustion which detects a reaction beforehand, which the reaction detecting element 5 detected beforehand with the reaction detecting element 5 and which controls fuel oil consumption or fuel injection timing according to a reaction stage beforehand at the time of compressed self-ignition combustion operation.

[0028] In addition, although the component of ECU1 can also constitute the reaction detecting element 5 and the fuel-injection control section 6 from the combustion pattern judging section 2, the jump-spark-ignition combustion-control section 3, the self-ignition combustion-control section 4, and a hard-wired logical circuit beforehand, it is realized as a program of a microcomputer with this operation gestalt.

[0029] Moreover, based on the engine revolution signal which the crank angle sensor 19 detected, and the accelerator opening signal (load) which the accelerator opening sensor (not shown) detected, ECU1 judges a service condition and computes fuel oil consumption and ignition timing. And based on this calculation result, a signal is sent to a fuel injection equipment 16 and an ignition plug 17.

[0030] In the basis of such a configuration, and this invention, while being shown in drawing 2, compressed self-ignition combustion is performed in the specific service condition below the number of a low load and middle turns, and jump-spark-ignition combustion is performed in a heavy load or a high rotational frequency region.

[0031] Next, actuation of this operation gestalt is explained. Drawing 3 shows the range where the self-ignition combustion to an air-fuel ratio is materialized. If the air-fuel ratio is made into Lean, combustion stability will get worse and an engine's torque fluctuation will become large. For this reason, a design value or the air-fuel ratio AFL from which the stability limitation which carries this internal combustion engine and can be permitted as character of a car etc. serves as the stability threshold value Sth serves as the Lean limitation as an internal combustion engine.

[0032] On the other hand, if the air-fuel ratio is made rich, knocking reinforcement will increase. Thereby, the air-fuel ratio AFR in the knocking limitation Nth serves as a rich limitation. Therefore, the stability limitation AFL and the air-fuel ratio field surrounded with the knocking marginal air-fuel ratio AFR serve as self-ignition combustion formation range. Thus, self-ignition is materialized only in the limited air-fuel ratio range. In addition, air-fuel ratio A/F was explained to the example as an index which shows the rate of gas and a fuel here. The same inclination is shown also about the case where residual gas or EGR gas is contained, and an axis of abscissa serves as the total capacity and fuel quantity rate G/F which doubled burned gas with new mind in this case.

[0033] Therefore, the compressed self-ignition combustion operating range in the conventional technique is shown in drawing 4. As shown in drawing, in the conventional technique, the compressed self-ignition combustion operating range has stopped at the very narrow range.

[0034] The cylinder internal pressure at the time of changing a combustion stage to drawing 5 and the combustion wave form of heat release are shown. The wave of a continuous line is a wave by the combustion stage just behind a compression top dead center, and the wave of a broken line is a wave which carried out the angle of delay of the combustion stage from the compression top dead center. If the angle of delay of the combustion stage is carried out, change of cylinder internal pressure will become loose. Since combustion is performed at the time of piston descent, this is because buildup of volume of combustion chamber negates a part of pressure buildup by combustion temperature and pressure variation is controlled.

[0035] $[dP/d\text{maximum } \theta]$ max and thermal efficiency of cylinder internal pressure rate of change per crank angle at the time of changing a combustion stage to drawing 6 are shown. A combustion stage serves as max just before a compression top dead center, and said $[dP/d\text{maximum } \theta]$ max reduces the maximum of the cylinder internal pressure rate of change used as the scale of the ease of generating of knocking as it carries out the angle of delay of the combustion stage from a compression top dead

center. moreover -- if thermal efficiency carries out the angle of delay of the combustion stage from a compression top dead center, although it gets worse -- extent of aggravation when there are few amounts of angles of delay -- it is very loose.

[0036] This is for a firing pressure and temperature to fall and for a cooling loss to fall, although time amount loss increases by lowering of a degree of constant volume. That is, since time amount loss and a cooling loss offset each other, even if it carries out the angle of delay of the combustion stage, thermal efficiency does not get worse. Therefore, in order to fall [dP/dmaximum theta] max of said cylinder internal pressure rate of change leading to knocking and to expand the operating range of compressed self-ignition combustion to a heavy load side, it is advantageous to carry out the angle of delay of the combustion stage to extent to which thermal efficiency does not fall.

[0037] As mentioned above, since it is influenced of residual EGR gas, the temperature in a cylinder differs slightly for every combustion cycle. The combustion wave form when whenever [cylinder internal temperature] changes to drawing 7 is shown. As shown in drawing 7 (a), when a combustion stage is near a compression top dead center and cycle variation occurs in whenever [cylinder internal temperature], the combustion wave form is stable.

[0038] On the other hand, when the angle of delay of the combustion stage is carried out, and cycle variation occurs in whenever [cylinder internal temperature], a combustion wave form will change [as shown in drawing 7 (b),] a lot. If this carries out the angle of delay of the combustion stage, it shows that stability gets worse. That is, in order to carry out the angle of delay of the combustion stage, it is necessary to improve the robustness (robustness) over cycle variations, such as whenever [cylinder internal temperature].

[0039] With the 1st operation gestalt, the fuel is injected in 2 steps. By injecting a fuel in 2 steps, the fuel started combustion at once, and became rapid combustion, and it has prevented that knocking occurs. The tooth lead angle of the 1st fuel injection timing is carried out more nearly enough [than a compression top dead center]. 2nd fuel injection timing is made into near a compression top dead center, and is controlling the firing stage by controlling this 2nd fuel oil consumption or fuel injection timing.

[0040] Since combustion of a gasoline is a low-temperature-oxidation reaction, after [which can do an intermediate product] going through a reaction beforehand, it results in the thermal flame which is final oxidation reaction. It mixes with oxygen and the fuel injected in the cylinder runs said reaction. If whenever [progress / of a reaction] is beforehand seen at this time, the initiation stage of self-ignition combustion can be predicted. That is, the robustness over variations, such as whenever [cylinder internal temperature], can be improved by [of the fuel injected by the 1st time] detecting the stage of a reaction beforehand and amending the 2nd fuel injection timing according to the result.

[0041] Drawing 8 shows the control approach of the fuel injection timing in this operation gestalt, and shows a fuel-injection pulse signal and heat release on the same time-axis. The drawing solid line A shows a usual fuel-injection pulse signal and the usual usual heat release. A broken line B shows a fuel-injection pulse and heat release when whenever [cylinder internal temperature] falls by a certain reason, when not performing control by this invention. An alternate long and short dash line C shows the fuel-injection pulse and heat release at the time of lowering whenever [under control of ECU of this operation gestalt / cylinder internal temperature].

[0042] If a reaction begins [the fuel which was injected by the 1st time in any case] beforehand, cylinder internal pressure will rise beforehand for generation of heat by the reaction. The cylinder internal pressure sensor 18 detects this cylinder internal pressure change. the reaction detecting element 5 detected and detected the reaction stage beforehand from change of this cylinder internal pressure sensor signal -- beforehand -- a reaction stage -- ***** -- it can judge [in which the anticipation combustion stage is carrying out the tooth lead angle how much than a target combustion stage / or or] whether the angle of delay is carried out by comparing a reaction stage. If the angle of delay of the fuel injection timing of the 2nd time will be carried out if the anticipation combustion stage is carrying out the tooth lead angle, and the anticipation combustion stage is carrying out the angle of delay by this judgment, the fuel-injection control section 6 will control to carry out the tooth lead angle of the 2nd

fuel injection timing. Thereby, a combustion stage is controllable as a target to be shown in the alternate long and short dash line C of drawing 8 .

[0043] In addition, although it is controllable at the combustion stage as a target even if it replaces with the tooth lead angle of the 2nd fuel injection timing, it replaces with a fuel oil consumption [2nd] loading or the angle of delay of the 2nd fuel injection timing as control of the fuel-injection control section 6 and it decreases the quantity of the 2nd fuel oil consumption, there is a fault accompanied by some fuel consumption aggravation and torque fluctuation.

[0044] Next, the control flow of this operation gestalt is explained to a detail with reference to the flow chart of drawing 9 . Rough actuation of drawing 9 is explained first. A service condition is judged and it branches to jump-spark-ignition combustion and compressed self-ignition combustion. the fuel which, detected cylinder internal pressure after the 1st fuel injection, and was injected by the 1st time in the operating range of compressed self-ignition combustion based on change of this cylinder internal pressure -- a reaction stage is judged beforehand. And if the angle of delay of the 2nd fuel injection timing will be carried out if the reaction stage has carried out the tooth lead angle beforehand compared with the predetermined stage, and the reaction stage has carried out the angle of delay beforehand, the tooth lead angle of the 2nd fuel injection timing will be carried out. Thereby, the optimal compressed self-ignition stage is obtained.

[0045] In drawing 9 , first, an accelerator opening signal and a crank angle signal are detected at step 10 (a step is hereafter abbreviated to S), and an engine speed and a load are computed by S11.

Subsequently, with reference to a map like drawing 2 memorized beforehand, a combustion condition is judged from an engine speed and a load by S12.

[0046] When a combustion condition judges it as jump-spark-ignition combustion, it progresses to S13, and control of jump-spark-ignition combustion is started. When it is judged as self-ignition combustion, it progresses to S14 and control of compressed self-ignition combustion is started. Subsequently, first fuel injection is performed at the stage which carried out the tooth lead angle from the compression top dead center by S15. Subsequently, a cylinder internal pressure sensor (sign 18 of drawing 1) detects cylinder internal pressure by S16. The reaction detecting element 5 computes the amount of heat release based on cylinder internal pressure beforehand by S17, and the reaction stage CT is computed beforehand. Subsequently, the 2nd fuel injection timing IT 2 is called in from the map of drawing 10 by S18.

[0047] Subsequently, the validity of a reaction stage is beforehand judged by S19. that is, a map as shown in drawing 11 is searched, and it is obtained -- ***** -- the reaction stage CT is compared beforehand, CT is carrying out the tooth lead angle to CTA, or having been computed judges whether it is almost equal or the angle of delay is carried out to be the reaction stage CTA, and this judgment result amends the 2nd fuel injection timing.

[0048] for example, -- beforehand -- the reaction stage CT -- ***** -- since the reaction stage has carried out the tooth lead angle beforehand in being smaller than reaction stage CTA-alpha (for example, alpha= 1), it branches to S20 and the angle of delay of the 2nd fuel injection timing IT 2 is carried out to IT2+beta.

[0049] beforehand -- the reaction stage CT -- ***** -- since the reaction stage has carried out the angle of delay beforehand in being larger than reaction stage CTA+alpha (for example, alpha= 1), it branches to S21 and the tooth lead angle of the 2nd fuel injection timing IT 2 is carried out to IT2-beta. In CTA-alpha<=CT<=CTA+alpha, adjustment of the 2nd fuel injection timing is not performed, but it moves to it S22. And it carries out at the stage which amended the 2nd fuel injection by S22.

[0050] Drawing 10 is the map of the 2nd fuel injection timing IT 2 of the criterion by the engine speed and the load. Since the relative time amount for evaporation of the fuel injected by the 2nd time or refining becomes short, the tooth lead angle of the fuel injection timing is carried out as an engine speed becomes high. Since fuel oil consumption decreases and lighting becomes difficult as a load becomes small, the tooth lead angle of the fuel injection timing is carried out.

[0051] drawing 11 -- ***** -- it is the map of the reaction stage CTA. an engine speed becomes high -- since it is alike, and it follows and the relative time amount for the chemical reaction of combustion

becomes short -- ***** -- the tooth lead angle of the reaction stage is carried out. a load becomes small -- since it is alike, and it follows, fuel oil consumption decreases and lighting becomes difficult -- ***** -- the tooth lead angle of the reaction stage is carried out.

[0052] Drawing 12 shows the compressed self-ignition range of inflammability of this operation gestalt by the service condition, and the conventional compressed self-ignition range of inflammability. As shown in drawing, compared with the conventional example, the range of compressed self-ignition combustion is substantially expandable to a heavy load side with this operation gestalt.

[0053] Next, the 2nd operation gestalt of this invention is explained. Drawing 13 is system configuration drawing showing the configuration of the 2nd operation gestalt of the combustion control system of the internal combustion engine concerning this invention. Although the configuration of the 2nd operation gestalt is the same as the configuration of the 1st operation gestalt shown in drawing 1 almost, having added the adjustable valve timing device 20 in which the valve timing of an inlet valve 14 and an exhaust valve 15 is changed, to the 1st operation gestalt differ.

[0054] The 2nd operation gestalt is characterized by the thing of the sealing stage when it could switch at while operating the valve timing for jump-spark-ignition combustion, and the valve timing for compressed self-ignition combustion, and both pumping bulbs have closed the 1st fuel injection under compressed self-ignition combustion in the exhaust stroke according to the adjustable valve timing device 20 to perform.

[0055] In drawing 14 (a), the valve timing at the time of jump-spark-ignition combustion and a valve lift, and drawing 14 (b) show the fuel-injection pulse signal at the time of compressed self-ignition combustion, and drawing 14 (c) shows the valve timing and the valve lift at the time of compressed self-ignition combustion, respectively.

[0056] At the time of compressed self-ignition combustion, the exhaust valve is closed earlier than an exhaust stroke top dead center in the middle of the exhaust stroke. Moreover, since the angle of delay of the stage which an inlet valve opens is fully carried out from the top dead center, before an inlet valve opens, the sealing stage which both pumping bulbs have closed exists. Both 1st fuel injection is performed at the sealing stage which said pumping bulb has closed, and 2nd fuel injection is performed near a compression top dead center.

[0057] In order to close earlier [an exhaust valve] than a top dead center, the gas after the combustion which was not exhausted is sealed and compressed into a cylinder. The gas after the combustion which was an elevated temperature from the first becomes an elevated temperature further by this compression. If a fuel is injected in the cylinder of such an ambient atmosphere of elevated-temperature high voltage, refining of a fuel will progress. Consequently, the ignitionability of a fuel improves and a reaction stage carries out a tooth lead angle beforehand.

[0058] The heat release stage A of the 1st operation gestalt (continuous-line display) and the heat release stage B of the 2nd operation gestalt (broken-line display) are shown in drawing 15 . With this operation gestalt, since refining of the fuel injected by the 1st time is progressing from the 1st operation gestalt, the generating stage of a reaction has carried out the tooth lead angle beforehand. Moreover, since the fuel injected by the 1st time is reforming and ignitionability is improving, the angle of delay also of the fuel injection timing which is the 2nd time is carried out.

[0059] Therefore, there is time amount from the detection stage of a reaction to the 2nd fuel injection timing beforehand, and the long operation time in ECU1 can be taken compared with the 1st operation gestalt. Consequently, decision of a reaction stage and control of the 2nd fuel injection timing can carry out with a sufficient precision beforehand.

[0060] Moreover, since the fuel injected by the 1st time is reforming, it can reduce unburnt [HC]. The control flow of a ***** 2 operation gestalt is the same as flows-of-control drawing 9 R> 9 of the 1st operation gestalt.

[0061] Next, the 3rd operation gestalt is explained. The configuration of the 3rd operation gestalt is the same as the configuration of the 1st operation gestalt shown in drawing 1 . The 3rd operation gestalt makes fuel injection in 1 cycle 1 time, and performs it near a compression top dead center. Moreover, it is characterized by performing amendment of fuel injection timing based on the cylinder internal

pressure and temperature hysteresis to near a compression top dead center.

[0062] With the 3rd operation gestalt, in order to inject a fuel at once, the inclination for combustion to tend to become rapid is shown. Therefore, it is necessary to carry out the angle of delay of the combustion stage further, and to control a combustion stage with a sufficient precision. On the other hand, since fuel injection per 1 cycle is made into 1 time, calculation of the fuel injected is easy and control of an air-fuel ratio can keep precision high.

[0063] The comparison with the heat release stage A of the 1st operation gestalt (continuous-line display) and the heat release stage B of the 3rd operation gestalt (broken-line display) is shown in drawing 16. With the 3rd operation gestalt, since there is no fuel into a cylinder until fuel injection is performed near a compression top dead center, a reaction does not occur beforehand. Therefore, fuel injection timing near a compression top dead center cannot be beforehand amended from a reaction stage like the 1st operation gestalt. For this reason, with the 3rd operation gestalt, it asks for whenever [cylinder internal temperature] based on the cylinder internal pressure which the cylinder internal pressure sensor 18 detected with a certain sampling period, a firing stage is predicted based on whenever [cylinder internal pressure and cylinder internal temperature], and the description is to amend the fuel injection timing near a compression top dead center according to this predicted firing stage.

[0064] Drawing 17 shows inverse number $1/\tau$ of the ignition-delay time amount τ of the gasoline mixture to the temperature in a constant-volume machine, and a pressure. It is shown that a fuel tends to be lit, so that $1/\tau$ of inverse numbers τ of ignition-delay time amount is large.

[0065] Moreover, in drawing 17, the example of the temperature in a compression stroke and the hysteresis of a pressure is shown. The firing stage of compressed self-ignition when a pressure and temperature change continuously can be predicted using inverse number $1/\tau$ of the ignition-delay time amount in a constant-volume machine. This is attained by integrating $1/\tau$ and calculating $\int 1/\tau dt$ (= it being called BP and a following firing characteristic) according to the temperature in the cylinder of each cycle, and the hysteresis of a pressure.

[0066] That is, from immediately after compression initiation, cylinder internal pressure is detected with a certain sampling period (ΔT), the temperature according to this pressure is computed, the map of drawing 17 is searched from these pressures and temperature, and it asks for $1/\tau$. And $BP = \int 1/\tau dt$ and the time of $\sigma [(1/\tau) \times \Delta T]$ reaching firing level (value with $**1$) actually can be judged to be a firing stage.

[0067] Drawing 18 indicates heat release to be $BP = \int 1/\tau dt$ in each crank angle. By B to which whenever [cylinder internal temperature] fell, the value of BP is low to the usual fuel injection timing IT of A. Therefore, if fuel injection is performed by the IT usual in this condition, a firing stage will carry out the angle of delay, and combustion will become instability.

[0068] On the other hand, when it judges whether predetermined judgment level is reached in a certain judgment stage before fuel injection timing in the value of BP and judgment level is not reached, the case where the tooth lead angle of the fuel injection timing IT in a compression stroke is carried out is shown in C. Whenever [cylinder internal temperature] can fall, and in consideration of the part to which the reaction time to firing became long, when only the amount β of amendments carries out the tooth lead angle of the fuel injection timing IT, it can control to carry out compression ignition combustion at a target stage.

[0069] Next, the control flow of the 3rd operation gestalt is explained with reference to the flow chart of drawing 19. The rough flow of control is the same as that of drawing 9 which is the flow chart of the 1st operation gestalt. Different points from the 1st operation gestalt are a tooth lead angle, maintenance, and a point that carries out the angle of delay about fuel injection timing in a compression stroke by calculation and the decision result of the firing characteristic BP for the firing stage prediction not more than S35.

[0070] A cylinder internal pressure sensor detects the cylinder internal pressure P by S35. T is computed whenever [cylinder internal temperature] from the cylinder internal pressure P so that it may mention later by S36. Subsequently, a map like drawing 17 is searched with S37, for example from whenever [cylinder internal pressure P and cylinder internal temperature / T], and it asks for inverse number $1/\tau$

tau of the ignition-delay time amount tau. Firing characteristic $BP = \text{integral} 1 - / \text{taudt}$ is computed by S38. It judges whether it is the decision stage of a firing characteristic by S39, and if it still is not a decision stage, it will return to S35 and the addition of the firing characteristic BP will be continued.

[0071] If it is a decision stage, the fuel injection timing IT of setting out will be called in by S40. The gap with the value and desired value gamma of firing characteristic $BP = \text{integral} 1 - / \text{taudt}$ is judged by S41. When BP is smaller than a lower limit (gamma-0.01), it predicts that a firing stage is overdue and the tooth lead angle of the fuel injection timing is carried out by S42.

[0072] When BP is larger than an upper limit (gamma+0.01), it predicts that a firing stage carries out a tooth lead angle, and the angle of delay of the fuel injection timing is carried out by S43. If a gap of the value of BP is in [from desired value gamma] a limit (gamma-0.01 <= BP <= gamma + 0.01), a setting-out change of fuel injection timing will not be made. And fuel injection in a compression stroke is performed by S44.

[0073] How to compute T whenever [cylinder internal temperature] from the cylinder internal pressure P in S36 here is explained. This calculation approach is an approach called combustion analysis, and computes whenever [cylinder internal temperature] for the alliance differential equation of the following three equations by solution Lycium chinense.

[0074]

[Equation 1]

The 1st principle of thermodynamics $dQ = dU + dW$ -- (1)

Equation of state $PV = mRT$ -- (2)

Internal energy type $dU = d(m \cdot C_v \cdot T)$ -- (3)

here -- Q:charge heating value, U:internal energy, W:work, P:cylinder internal pressure, and V: -- it is C_v :specific heat at constant volume whenever [volume, number of m:mols R:gas constant, and T:cylinder internal temperature].

[0075] The polytropic index for every crank angle can be found by solution Lycium chinense in the above three formulas, and whenever [cylinder internal temperature] can be predicted with a sufficient precision. It is called combustion analysis, this solution method is well-known for this contractor, and since it also requires paper width, it is omitted for details.

[0076] Moreover, although it can also ask for T based on polytropic change whenever [cylinder internal temperature], since the intake-air-temperature sensor for acquiring the initial temperature T0 was needed and fixed polytropic-index n is always assumed among a cycle, precision falls a little. Below, the temperature formula by polytropic change is shown.

[0077]

[Equation 2]

$T = T_0 \times (V_0/V)^{(n-1)}$ -- (4)

Here, they are V:volume, the initial temperature of T0:, the initial volume of V0:, and n:polytropic index whenever [T:cylinder internal temperature].

[0078] Next, the 4th operation gestalt is explained. The configuration of the 4th operation gestalt is the same as drawing 1 $R > 1$ which shows the configuration of the 1st operation gestalt. The 4th operation gestalt is characterized by changing the amount of amendments of the fuel injection timing near a compression top dead center when a reaction stage changes beforehand according to a target combustion stage. For this reason, in this operation gestalt, the interior of the fuel-injection control section 6 is equipped with the map of the target combustion stage BTA according to a service condition as shown in drawing 20, and the amount of amendments beta map of fuel injection timing according to a combustion stage as shown in drawing 21.

[0079] As mentioned above, the robustness of the combustion to the cycle variation of whenever [cylinder internal temperature] changes with combustion stages. The robustness of combustion falls, so that a combustion stage carries out the angle of delay from a compression top dead center. Therefore, when a combustion stage carries out the angle of delay, the amount of amendments of the fuel injection timing near a compression top dead center when a reaction stage changes beforehand is enlarged. Consequently, it cannot be based at a combustion stage but the robustness of combustion can be

improved.

[0080] Next, the control flow of the 4th operation gestalt is explained with reference to the flow chart of drawing 22. The rough flow of control is the same as that of drawing 9 which is the flow chart of the 1st operation gestalt.

[0081] Only a different place from the 1st operation gestalt is explained. The target combustion stage BTA is called in from a map like drawing 20 by S59. If the reaction stage CT is beforehand judged by S60 and the reaction stage has carried out the tooth lead angle beforehand ($CT < CTA - \alpha$), the amount beta of amendments will be calculated from the target combustion stage BTA by S61, and only the amount beta of amendments will carry out the angle of delay of the 2nd fuel injection timing IT 2 by S62. If the reaction stage has carried out the angle of delay beforehand ($CT > CTA + \alpha$), the amount beta of amendments will be calculated from the target combustion stage BTA by S63, and only the amount beta of amendments will carry out the tooth lead angle of the 2nd fuel injection timing IT 2 by S64. In $CTA - \alpha \leq CT \leq CTA + \alpha$, adjustment of the 2nd fuel injection timing is not performed, but it moves to it S65. And it carries out at the stage which amended the 2nd fuel injection by S65.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the block diagram of the 1st operation gestalt of the combustion control system of the internal combustion engine concerning this invention.

[Drawing 2] It is drawing explaining the combustion pattern to a service condition.

[Drawing 3] It is drawing explaining the self-ignition formation range.

[Drawing 4] It is drawing explaining the compressed self-ignition combustion operating range of the conventional technique.

[Drawing 5] It is drawing explaining the combustion wave form over a combustion stage.

[Drawing 6] It is drawing explaining the maximum $[dP/d\theta_{max}]$ and thermal efficiency of the cylinder internal pressure R/C over a combustion stage.

[Drawing 7] It is drawing explaining the robustness of the combustion to a combustion stage.

[Drawing 8] It is drawing explaining the combustion stability of the 1st operation gestalt.

[Drawing 9] It is control flow chart drawing of the 1st operation gestalt.

[Drawing 10] It is the 2nd fuel-injection-timing (IT2) map to an engine speed and a load.

[Drawing 11] an engine speed and a load are received -- ***** -- it is a reaction stage (CTA) map.

[Drawing 12] It is drawing explaining the compressed self-ignition combustion operating range of the 1st operation gestalt.

[Drawing 13] It is the block diagram of the 2nd operation gestalt.

[Drawing 14] It is drawing explaining the valve timing of the 2nd operation gestalt.

[Drawing 15] It is drawing explaining the heat release of the 2nd operation gestalt.

[Drawing 16] It is drawing explaining the heat release of the 3rd operation gestalt.

[Drawing 17] It is drawing explaining 1/of inverse numbers tau of the ignition-delay time amount tau over temperature and a pressure.

[Drawing 18] It is drawing explaining the combustion stability of the 3rd operation gestalt.

[Drawing 19] It is control flow chart drawing of the 3rd operation gestalt.

[Drawing 20] It is drawing explaining the target combustion stage to an engine speed and a load.

[Drawing 21] It is drawing explaining the amount beta of amendments of the fuel injection timing (IT) to a target combustion stage.

[Drawing 22] It is control flow chart drawing of the 4th operation gestalt.

[Description of Notations]

1 ECU

2 Combustion Pattern Judging Section

3 Jump-Spark-Ignition Combustion-Control Section

4 Self-ignition Combustion-Control Section

5 It is Reaction Detecting Element Beforehand.

6 Fuel-Injection Control Section

10 Engine

11 Inlet Port

- 12 Exhaust Port
- 13 Piston
- 14 Intake Valve
- 15 Exhaust Air Bulb
- 16 Fuel Injection Equipment
- 17 Ignition Plug
- 18 Cylinder Internal Pressure Sensor
- 19 Crank Angle Sensor
- 20 Adjustable Valve Timing Device

[Translation done.]

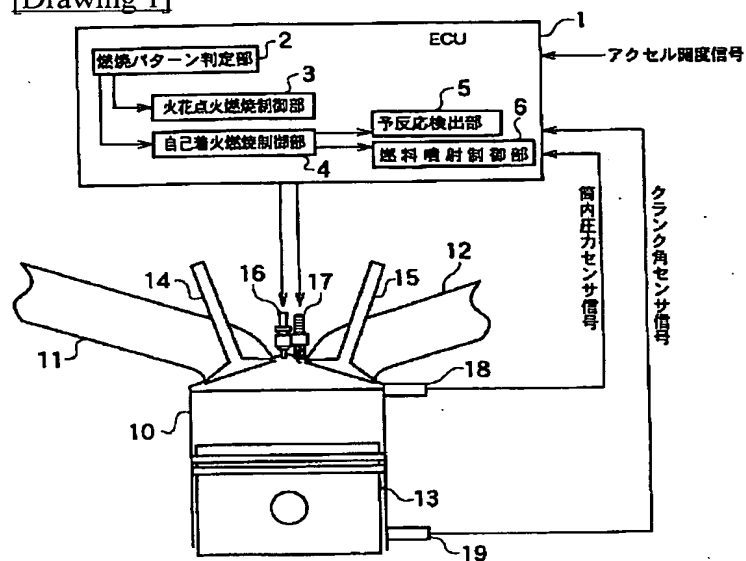
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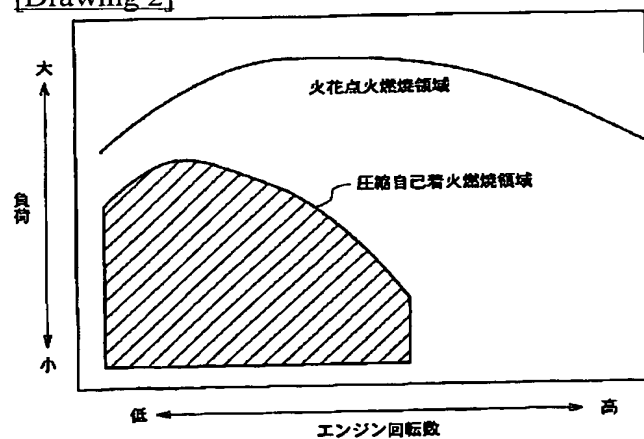
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DRAWINGS

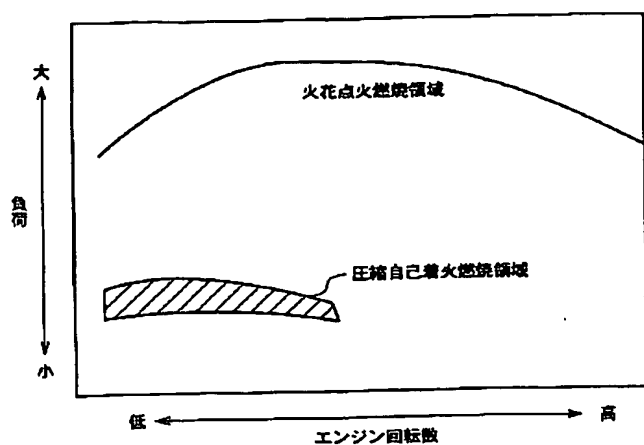
[Drawing 1]



[Drawing 2]

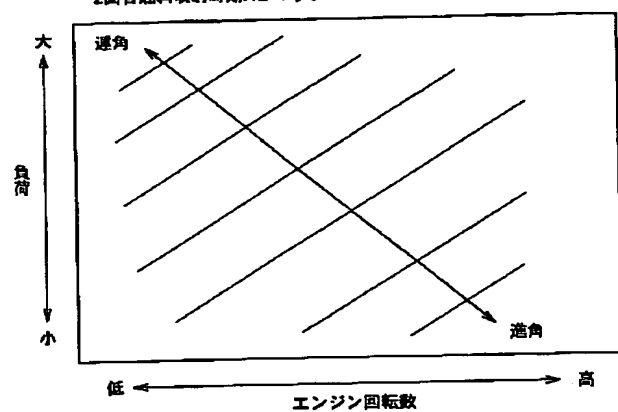


[Drawing 4]

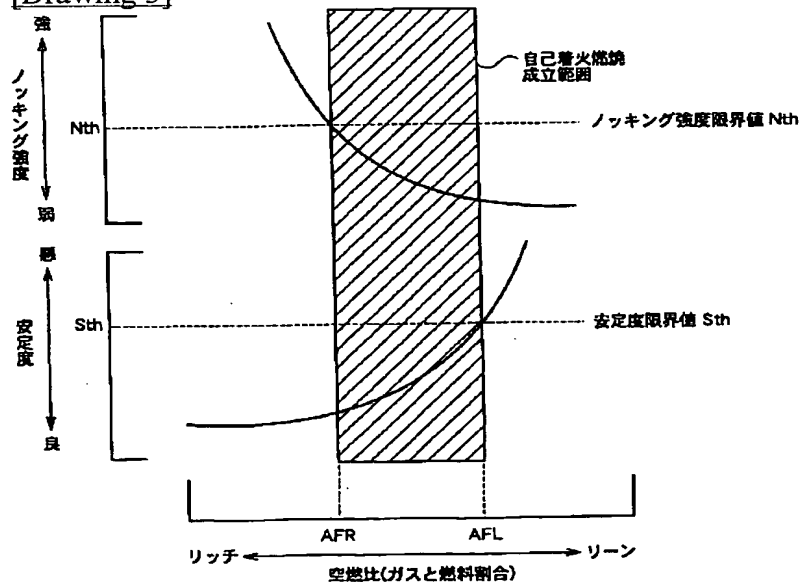


[Drawing 10]

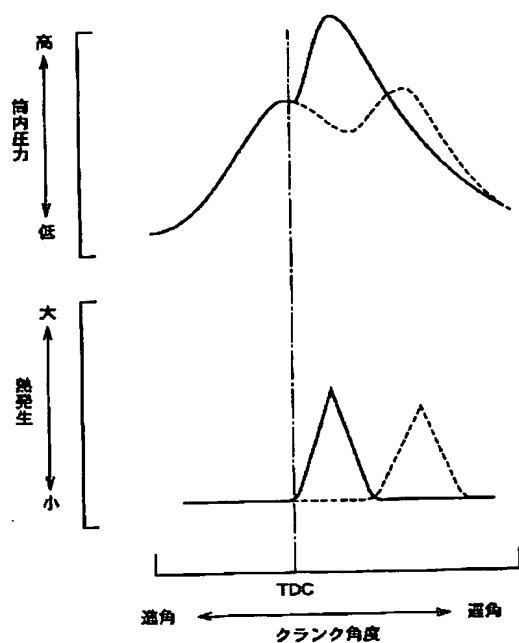
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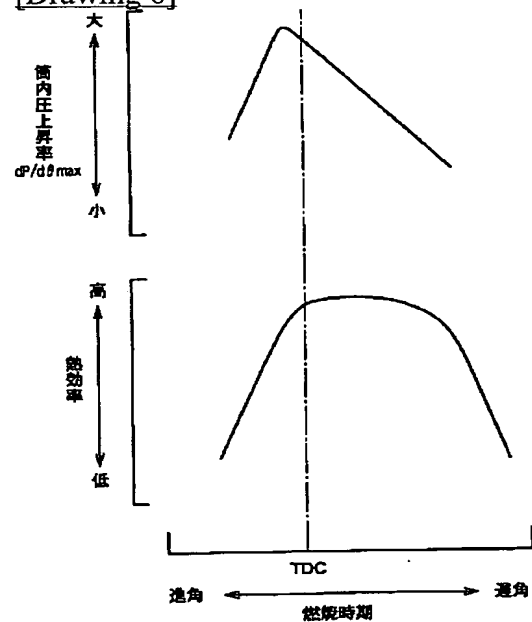
[Drawing 3]



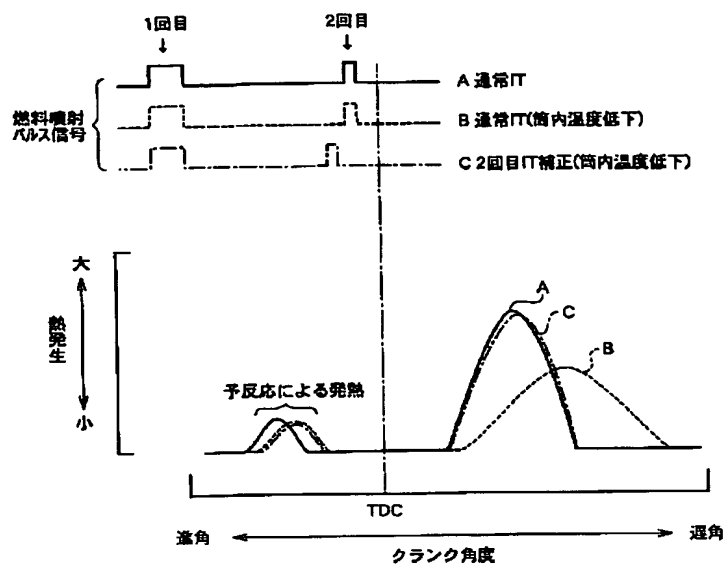
[Drawing 5]



[Drawing 6]



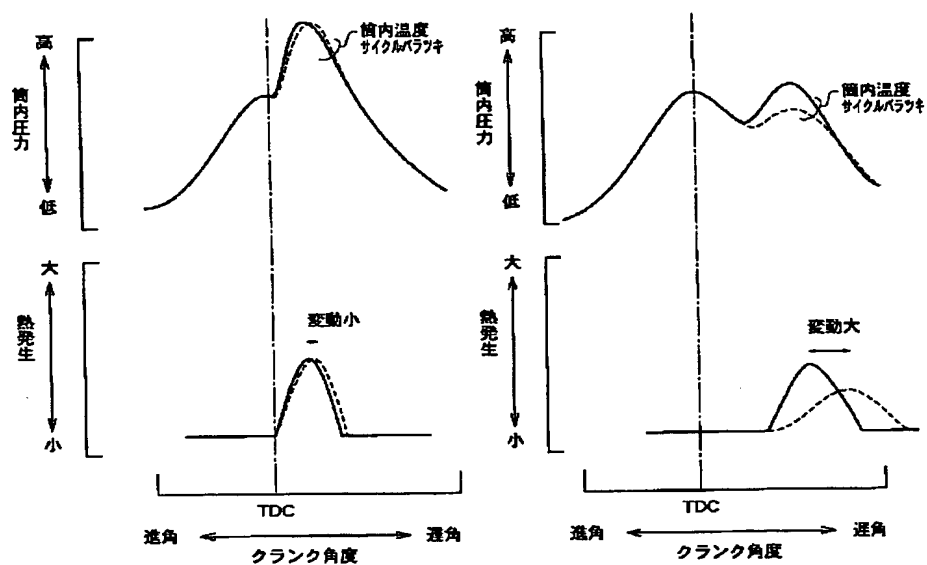
[Drawing 8]



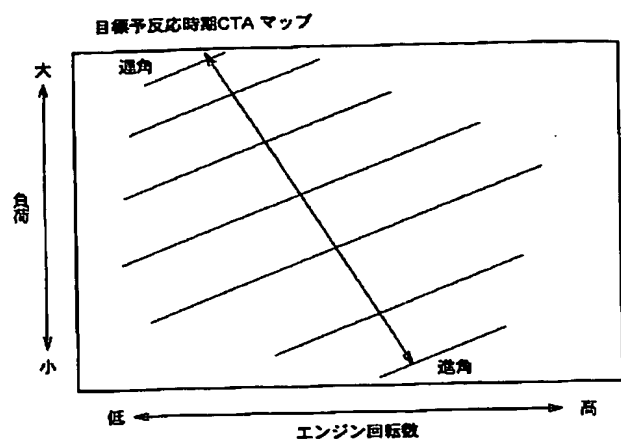
[Drawing 7]

(a) 上死点付近の燃焼波形

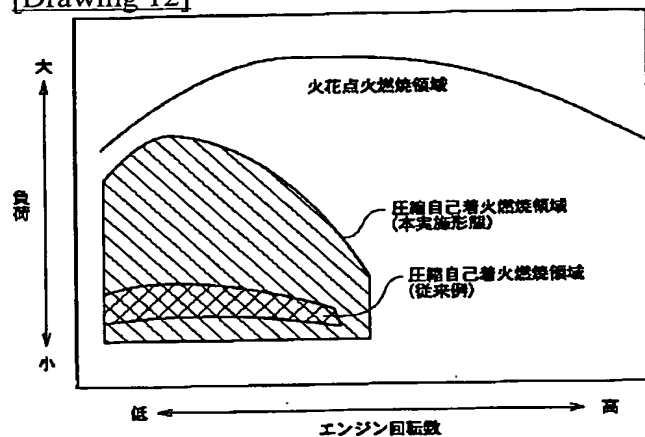
(b) 遅角した燃焼波形



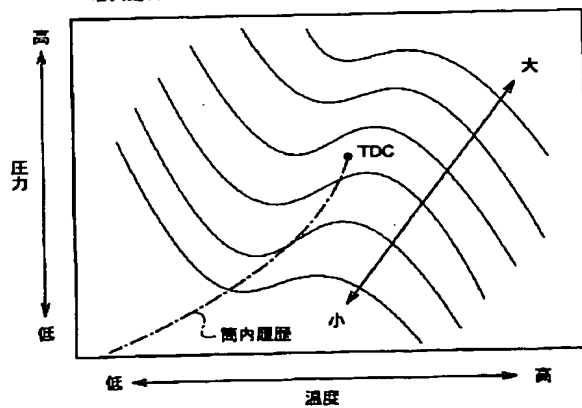
[Drawing 11]



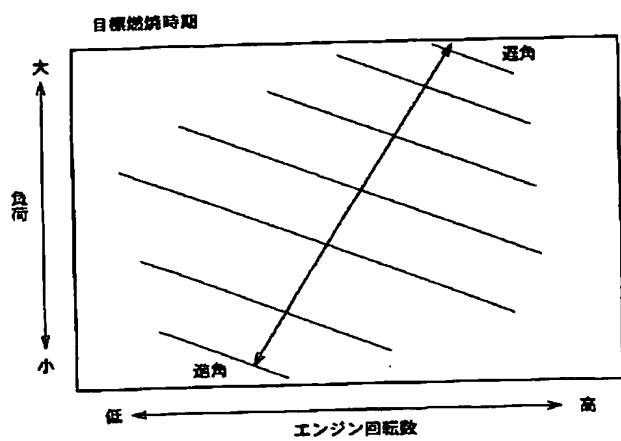
[Drawing 12]



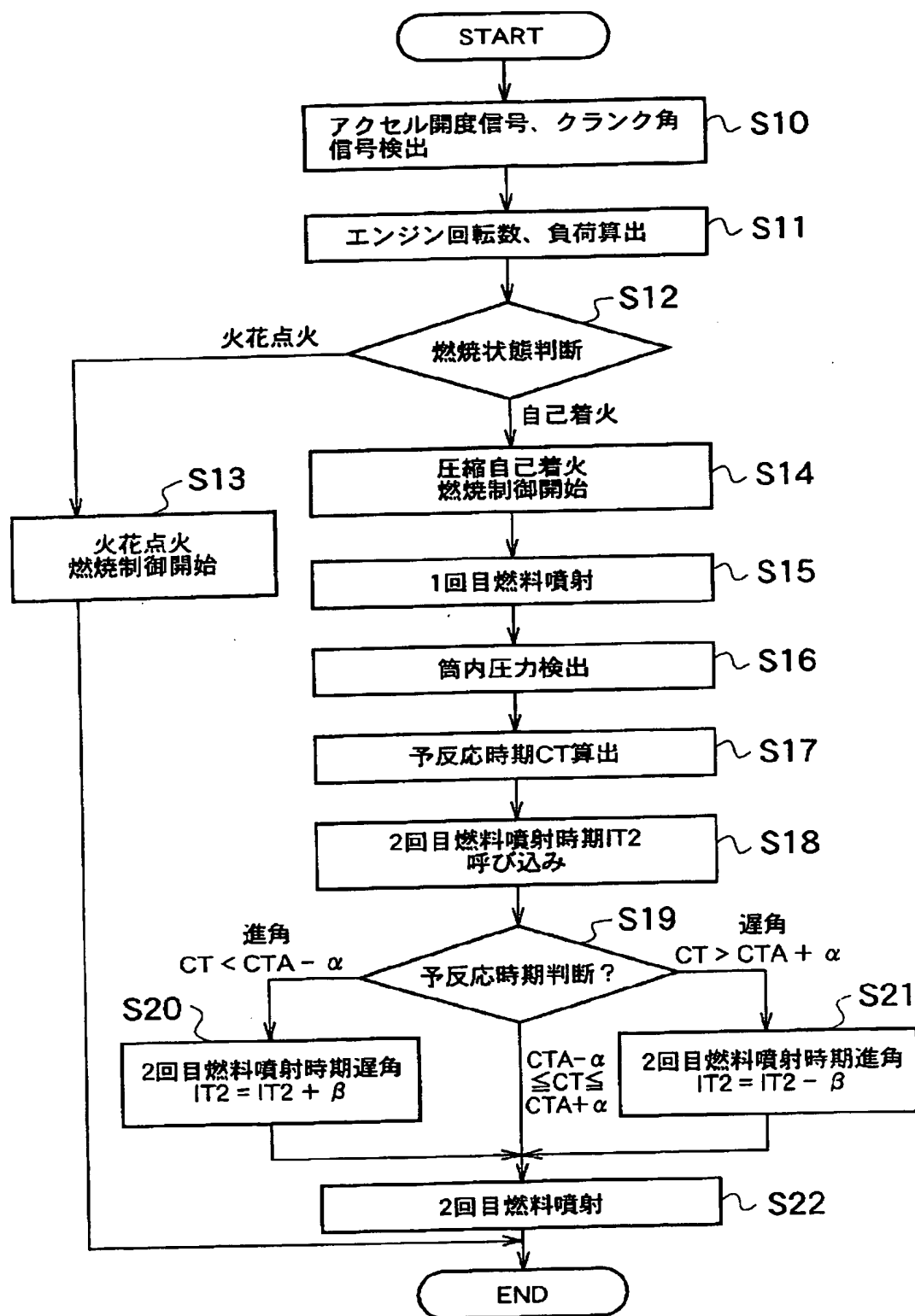
[Drawing 17]

着火遅れ時間 τ の逆数 $1/\tau$ 

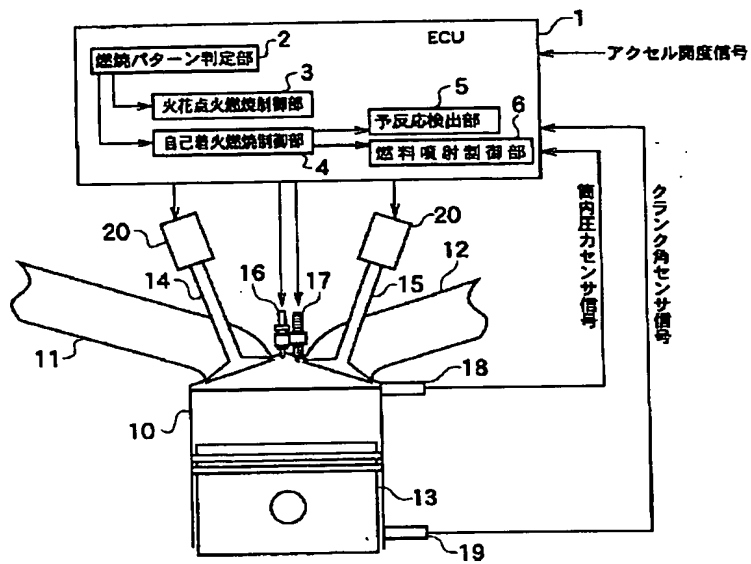
[Drawing 20]



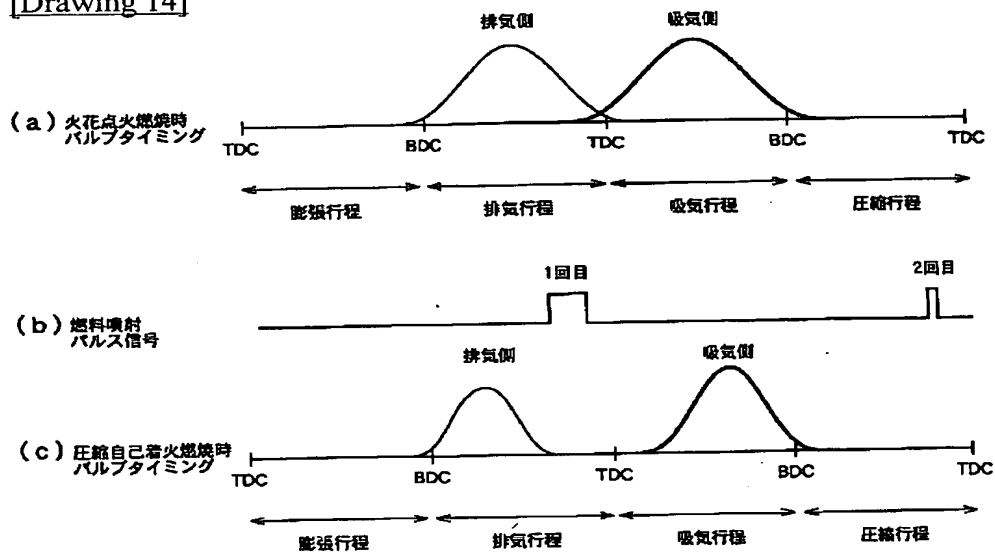
[Drawing 9]



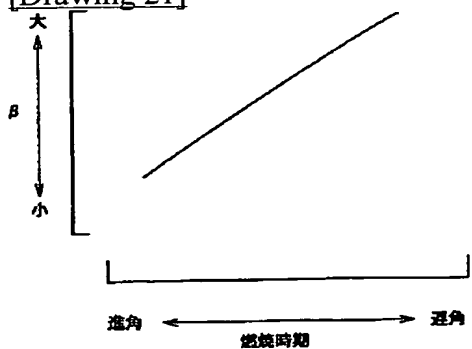
[Drawing 13]



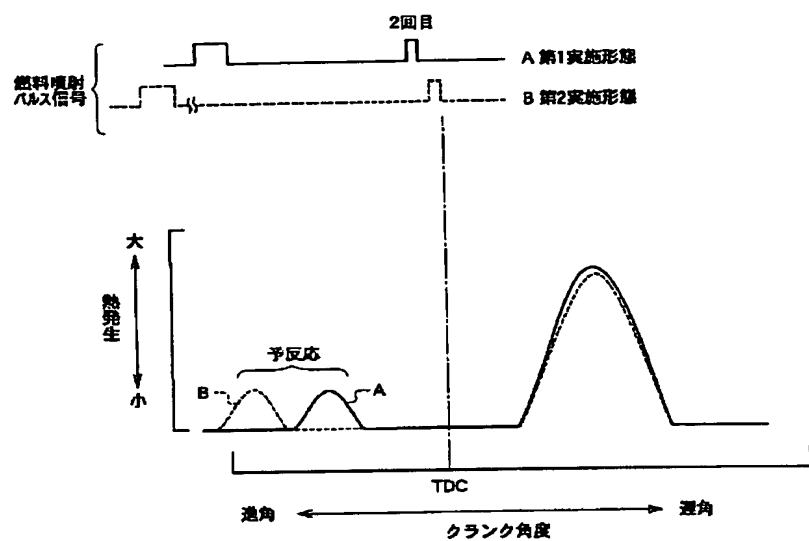
[Drawing 14]



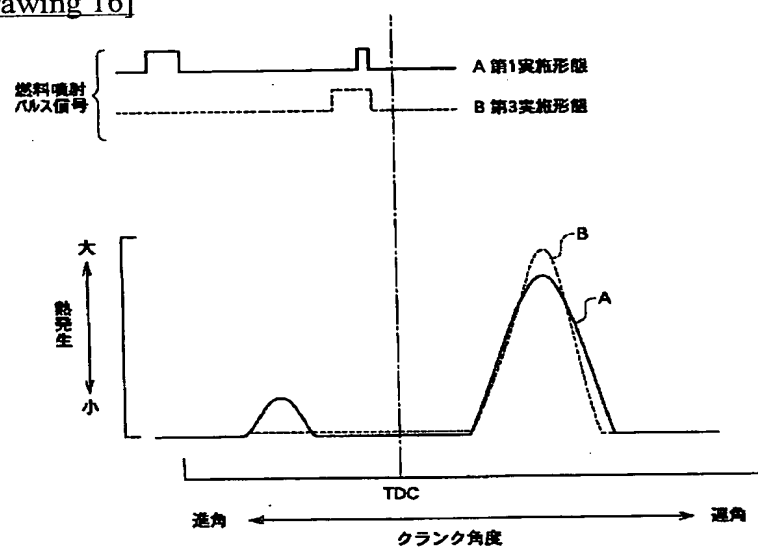
[Drawing 21]



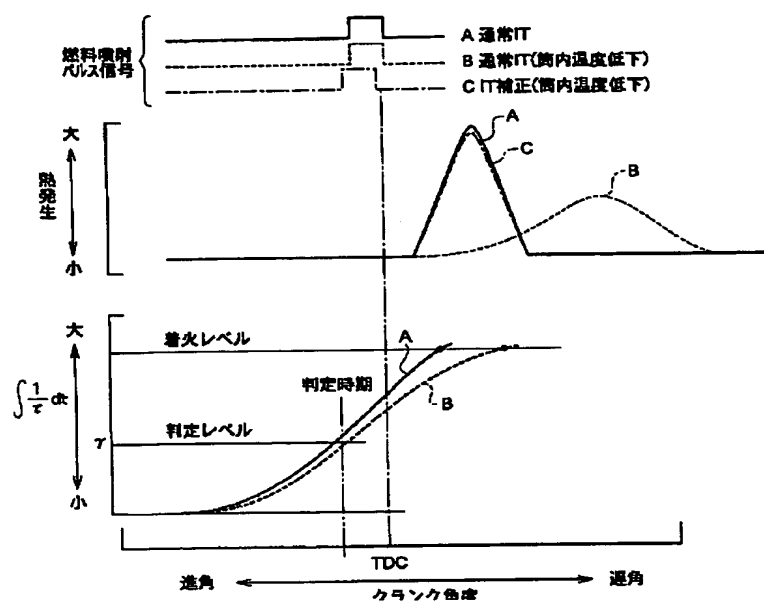
[Drawing 15]



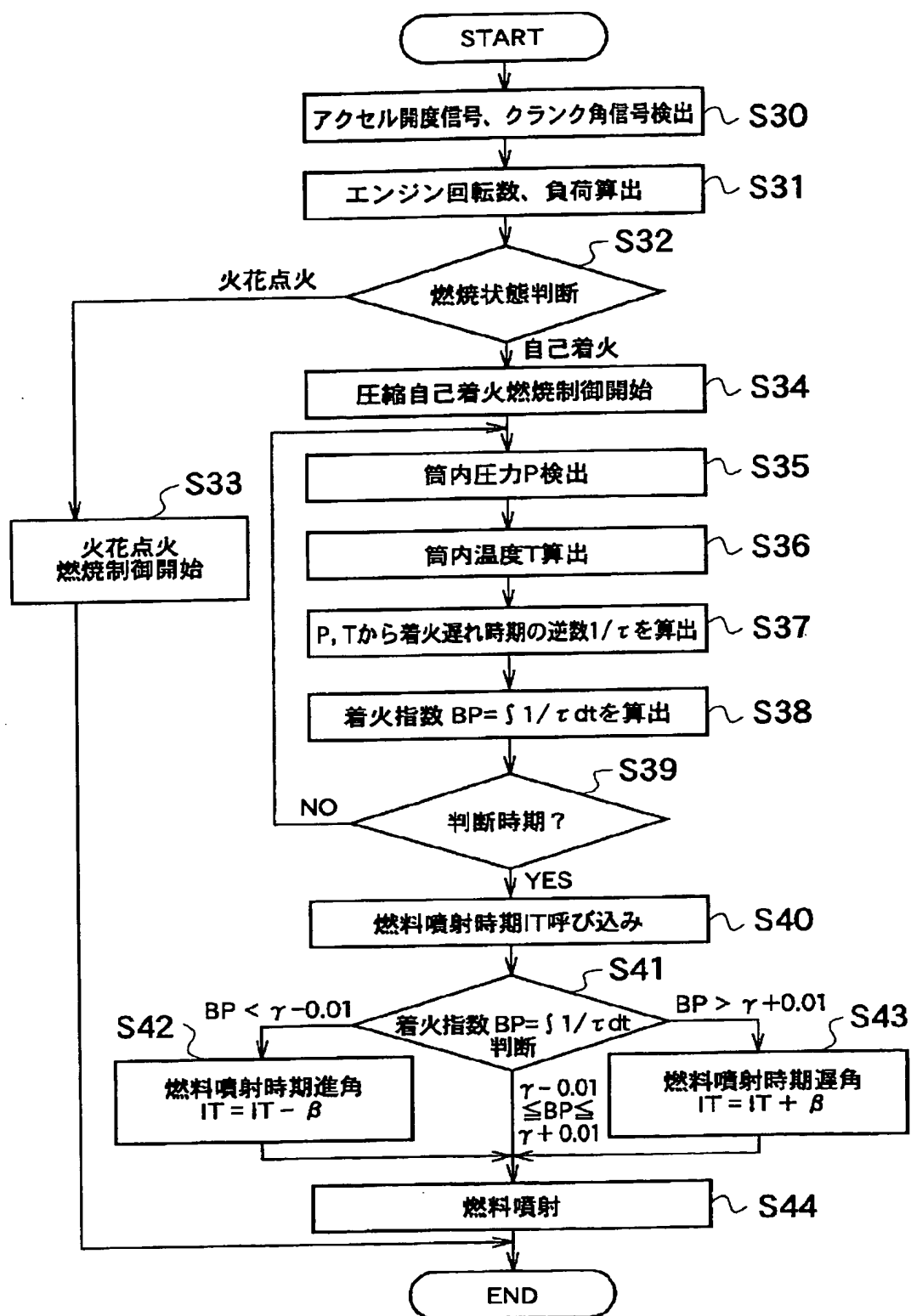
[Drawing 16]



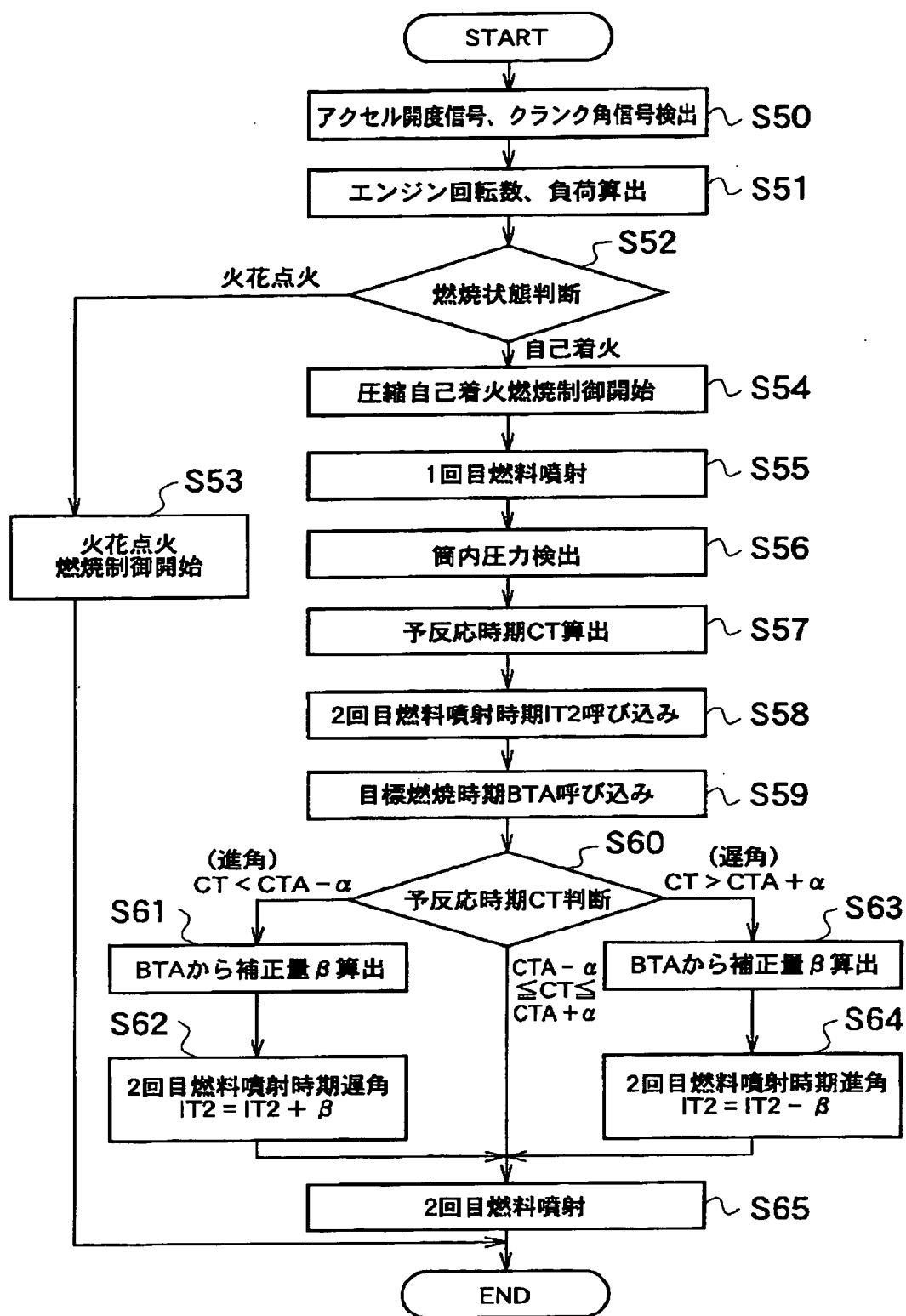
[Drawing 18]



[Drawing 19]



[Drawing 22]



[Translation done.]